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CHARLES FRANKLIN KETTERING

PRESIDENT OF THE A.A.A.S. FOR 1945

By T. A. BOYD

"You have to be 'sold' on research before you can hope to get anywhere in it. . . . What you need is to be bitten by the research bug." This assertion exactly characterizes the man who made it—Charles F. Kettering, president of the American Association for the Advancement of Science for 1945. He was bitten by the research bug early in life, and to him, for forty years, research and science have been vocation, avocation, and vacation.

As head of the General Motors Research Laboratories, Dr. Kettering is director of a great deal of research, both fundamental and applied. But he still thinks it important to do actual experimentation himself. Otherwise, he says, it would be just as though a golfer were to get someone else to play his game for him, or as if a violinist were to hire a substitute to do his practicing for him. A fellow can't be a good golfer or violin player by reading books, he says.

Charles F. Kettering was born on August 29, 1876, on a farm near Loudonville, Ohio. He attended the country school in his district, graduated from the Loudonville High School, and then taught a country school for a year. The following summer he attended Wooster University (now The College of Wooster). While there he had the first severe occurrence of the trouble with his eyes, which during his young manhood made him almost blind for long periods. Later, having recovered somewhat, he taught the upper room of the grade school in Mifflin, Ohio, for two years.

In the fall of 1898 he entered the College of Engineering of The Ohio State University. But there again he was hampered by a recurrence of the trouble with his eyes, which toward the end of the year made it impossible for him even to read. Then, after coming back in the fall, he was soon forced to leave the University.

It was two years after that before he could return. But during those years he gained experience that was to have a large effect upon his future. Thinking that outdoor work might be good for him, he took a job with the construction gang of the Star Telephone Company. Beginning by digging holes for telephone poles, he soon became foreman of the gang. In that capacity he introduced an improved method of constructing telephone lines and of adjusting the height of poles to the grade by prior survey, and he developed a new system of splicing and testing telephone cables.

The fall of 1901 found him back at The Ohio State University. There, in spite of lingering difficulty with his eyes and of a degree of individuality and originality that made it hard for him to fit into a rigid school system, he made an outstanding record, having achieved the highest, or merit, standing in about one-half of his courses. While in the University, he supported himself in considerable part by serving as a telephone trouble-shooter. As an important addition to his other knowledge and experience in the telephone business, he had developed a simple electrical system of locating the source of trouble in telephone cables, which made him an expert in that field.

In 1904, at the age of twenty-eight, he graduated from The Ohio State University with the degree of M.E. in E.E. Because of his good record in the University and his

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extensive experience in the telephone field, he was employed by the National Cash Register Company. There as a member, and soon as head, of Inventions Department Number 3, he began his long and productive career in industrial research. He developed an electrically operated cash register, inventing for the purpose altogether new types of high-output electric motors. In the course of this development he designed what was a new form of AC–DC, or universal-type, electric motor. He next developed the O.K. telephone credit system by which charge-sales in department stores could be authorized by telephone from the central credit department. He developed also the hotel checking machine, which evolved later into the now extensive system of calculating and accounting machines. All this he did within a period of about five years.

Utilizing again his telephone background, he developed an improved battery ignition system for automobiles, in which the troublesome vibrator then in use was replaced by a controlling relay that gave only one positive spark per power stroke and thereby increased the life of batteries fivefold. This development he made with the aid of one of the first electric oscillographs to be manufactured in this country. "Without the oscillograph," he said, "I could not have developed battery ignition, for so much that was written on the subject of ignition was not so."

At this time he resigned from the National Cash Register Company to commercialize this new development. And that led him within a few months to launch into the development of the electric self-starter for automobiles also. In the self-starter he utilized again some of the principles he had employed in applying the electric motor to the cash register, notably that of a small high-torque motor operated at large overload because it ran only for brief intervals between longer periods of rest.

Kettering's work on battery ignition, the self-starter, and the engine-driven farm lighting set, which also he had developed meanwhile, led him into another field of importance in which he became the principal pioneer. This is the field of automobile and aviation fuels, where he has made a long and productive effort to overcome the principal defect of hydrocarbon fuels—the noisy and power-limiting bugbear of knock. Two of the results of this research are outstanding in importance. The first is the performance of the chemical antiknock agents (e.g., tetraethyl lead). The second is the fact that fuels composed of the straight-chain hydrocarbons, which make up petroleum for the most part, are particularly bad in respect to engine output as limited by knock, whereas those consisting of closely compacted molecules are very good. It was these two discoveries that pointed the way to the high-octane, or high-output, aviation gasoline that is proving to be of such paramount importance in the present war. "I think we wouldn't have won the battle of Britain without 100-octane," said Geoffrey Lloyd, Great Britain's Petroleum Secretary. That British fliers did have 100-octane gasoline, and that our own pilots have it too, is due primarily to the imagination and foresight of Dr. Kettering. He began research in the field of high-octane fuels even before the last war, and with his small staff of workers he has continued productive research in it ever since.

It was to get this project detached from production problems that Kettering organized in 1916 a new and separate research laboratory to work on the fuel problem. A few years later this laboratory was merged with General Motors Corporation and became part of the present Research Laboratories Division, of which he is still the active directing head. Out of this research laboratory, under the inspiration and guidance of Dr. Kettering, have come a great many advances of importance in the automotive field. These are too many to enumerate. But a major one, and one in which Dr. Kettering himself had a particularly large part, is the two-cycle Diesel engine, which already has wrought a revolution in the powering of railroads and which is proving of the greatest importance as power for ships, submarines, landing craft, and mobile power plants, as well as for trucks and busses.

In his own personal research, conducted under the Charles F. Kettering Foundation, Dr. Kettering has done active pioneering in several fields. One of these is his fundamental researches on chlorophyll and photosynthesis, or "why grass is green." Another

is his extensive investigation of fever therapy, resulting in the development of the Kettering Hypertherm which, under the guidance of the United States Public Health Service, is now being used effectively in the one-day treatment of venereal diseases. Still another—one in which he has a particular interest and to which he has personally devoted a great deal of experimentation—is the nature of magnetism and its relationship to electricity and chemical valency.

In the present war, as in the last, Dr. Kettering has been active in aiding the war effort. He has been conducting a number of researches, which cannot now be named, and he has been an adviser to the Army and the Navy and a consultant on radar to the War Production Board. He is also chairman of the National Inventors Council and of the National Patents Planning Commission.

In the field of aircraft Kettering has had extensive experience. He was one of the first Americans to fly his own airplane, having been taught to fly by Orville Wright himself. He used to fly twice a day, going aloft in all kinds of weather, partly to study meteorology. He was a pioneer in instrument flying, an early advocate of three-point and power landings, and one of the first to take photographs from the air. When he quit flying his own plane about fifteen years ago, he had had the largest number of hours in the air of any amateur pilot.

Dr. Kettering has been very active also in the business world as the organizer of several new companies and as president or other official of all of them. For many years he has served as a vice-president of General Motors Corporation. Although possessing great talent in the business world, he has consistently avoided being cast primarily as a business executive. This he has done in the belief that he can make his greatest contribution not as an administrator but as an originator and experimenter.

On August 1, 1905, Kettering married Miss Olive Williams of Ashland, Ohio. They have one son, Eugene W., who is assistant chief engineer of the Electromotive Division, General Motors Corporation.

The new president of the A.A.A.S. is a member of many other scientific and engineering societies, as he believes such organizations serve a vital purpose. He is a member of the National Academy of Sciences and a past-president of the Society of Automotive Engineers. He has received a great many honorary degrees and numerous awards and medals.

A very human person, Dr. Kettering likes people and gets along well with individuals of every rank. Among those who work for him and with him he is affectionately referred to as "Boss Ket." One of the reasons for his great success in developing new things for people to use is his understanding of the importance of the human factor.

Dr. Kettering is a trustee of Antioch College and of The Ohio State University, and chairman of the advisory board on the development of the Technological Institute of Northwestern University. Out of a life-long interest in education, he has formulated definite views on the subject. He thinks that young people should be taught to use their hands as well as their heads. They should be taught also how to get along with people and to work with them. On this account he is an active advocate of co-operative education. "We need to lap-weld young people on to life," he says, "instead of butt-welding them on."

Dr. Kettering is an unusually successful speaker. He has addressed many, many groups composed of all kinds of people. Of course, much of what he says relates to technical subjects, but he has such a remarkable faculty of expressing abstruse matters in common terms and he talks so much in simile, metaphor, and epigram, and with such frequent flashes of humor, that he is readily understood by everyone. In his view a thermometer is a molecular speedometer and the second law of thermodynamics means "that a fellow can't push on something that is going faster than he is."

It is particularly appropriate that Charles F. Kettering should be president of A.A.A.S., for he is perhaps doing as much as any man alive today both to advance the cause of science itself and to make it serve people in practical ways. Among his principal talents is his unusual ability as a salesman. And one of his greatest services has been to utilize that talent in selling research and the scientific method to people and to industry.

FELINE FISHERMEN

SOME ACCOUNTS OF FISHING BY DOMESTIC CATS

By E. W. GUDGER

THAT cats dislike getting even their feet wet and hence avoid water has been said so often and for so long that it has become almost an axiom. Indeed, one writer has dubbed the felines 'Catabaptists.' Also axiomatic is their great fondness for fishes. "Cats are crazy about fish," "The cat is an animated fish trap" are typical remarks.

Illustrative of this fish appetite in cats are two charming figures copied from Yarrell's *British Fishes* (ed. 2, 1841). These are vignettes, or tailpieces, to two chapters in his book and are not referred to in the text; they are included merely to show to what lengths cats will go to purloin their much-loved fish food. The house cat depicted in the first of these (Fig. 1) has just abstracted a fish from her master's basket hung on the back of the chair. Note her drooping tail and the anxious expression on her face as she looks about to see, before absconding, if anyone is witnessing the theft. In the other vignette (Fig. 2) the fisherman sits on a wall with his back to cat and creel and seeks to add another fish to the three already caught. One of these has been seized by the cat, which walks off sure of safety in the adjoining thicket of rushes—such at least the hoisted tail and the happy look on her face seem to indicate.

Furthermore, it is an assured fact that in the carnivorous family Felidae the fish appetite is stronger than the water phobia. As evidence of this I published in *Natural History,* in 1925, an article in which I brought together 38 accounts (brief or detailed) of wild or domestic cats that had been seen or reliably reported to have gone afishing. Some of the domestic cats merely accompanied their masters and seized the fishes when these were brought ashore by the anglers. Some reached down into the water with claw-filled paws and deftly hooked out their finny prey. Others went in "all over" and by swimming and diving caught their fishes with their paws or mouths. And one mother cat taught her kittens to follow her in headfirst and each to catch its minnow. The wild Felidae were reported to use essentially the same fishing methods as the domestic cats.

The publication of this article excited considerable interest and brought me letters giving personal observations and references in addition to those already utilized. Constant bibliographic work on fishes uncovered other citations of cats as enemies of fishes. And now, because of the interest in this unusual behavior of cats, it seems worth while

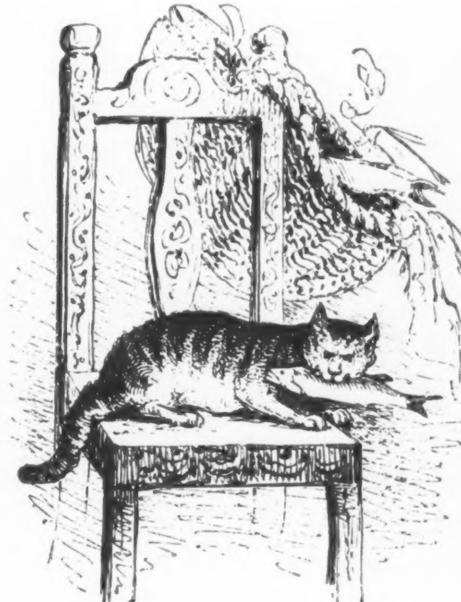

FIG. 1. THE FELINE FISH-THIEF
THE GUILTY LOOK AND DROOPING TAIL BETRAY THE CULPRIT. FROM YARRELL'S *British Fishes* (1841).

to bring these newly found and widely scattered data together. Furthermore, it has seemed well to devote this paper to fishing by tame cats and to defer to another time the story of fishing by the wild jaguars of South America, many of which are alleged to use the tail as a lure for fishes.

Fishing Exploits of European House Cats. Captain Thomas Brown in his delightful *Anecdotes of Animal Life* (1840) tells of a house cat that fished at Caverton Mill in Roxburghshire, Scotland. Her operation was as follows:

> When the mill work ceased, the water was, as usual, stopped at the dam-head; and below the dam, it consequently ran gradually more shallow, often leaving trout, which had ascended when the stream was full, to struggle back with difficulty. . . . And so well acquainted had puss become with this circumstance, and so fond was she of fish, that the moment she heard the noise of the mill-clapper cease, she used to scamper off [from the house two or three hundred yards away], to the dam and [below this] used to stand up to her belly in the water, and continued to catch fish like an otter.

J. G. Wood, in his *Sketches and Anecdotes of Animal Life* (1857), states that he

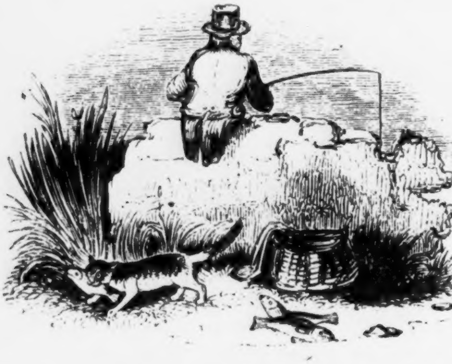

FIG. 2. ANOTHER FELINE FISH–STEALER CONFIDENTLY SLINKING AWAY WITH TAIL HOISTED HIGH. FROM YARRELL'S *British Fishes* (1841).

knew a cat at Oxford that was accustomed to fish from a wharf, whence she could look down on the fishes passing below. But, being an ethical fisherman, she would not touch any small fish and disdained "to enter the water for any fish less than a herring." The *modus operandi* of her fishing is not given, but presumably she went in all over.

In 1883, Simmermacher described in *Der Zoologischer Garten* an interesting occurrence at Offenbach in Germany. In a private garden there was a small pool stocked with goldfish. Here suddenly appeared a procession of cats coming singly. At noon, when the fish would bask at the surface near the edge of the pool, one of the cats would hang over the edge and with a dexterous paw would fling out a fish, then take it in its mouth and kill it. For 14 days this went on with great decimation of the fishes, and then the cats were frightened away by being shot at. The author gave no illustration, but fortunately there has come to hand a splendid photograph of just such an occurrence (Fig. 3). It shows a beautiful cat perched on the rockwork of a garden pool. The animal is cautiously tapping on the water, seemingly to entice the fish to come to the surface. The fish, however, wisely keep their distance.

In the third series of his interesting *Curiosities of Natural History* (1891), Frank Buckland tells of an old fisherman friend at Portsmouth who had a favorite cat named Puddles ("the wonderfullest water cat as ever come out of Portsmouth"). If he was not taken along when his master went fishing, Puddles would yowl until his master relented. He would never molest any of the fish his master had caught unless they were given to him, and he would go overboard for one kind only. The fisherman describes the cat's method as follows:

> When it was fine he used to stick up at the bow of the boat and sit a-watching for the dogs [*i.e.*, dogfish]. The dogs used to come alongside by thousands at a time, and when they was thick all about, he would dive in and fetch them out jammed in his mouth as fast as may be, just as if they was a parcel of rats. . . . He looked terrible wild about the head when he come up out of the water with the dogfish. It was a bad day when I lost my Puddles, he was the most superbest cat as ever was afloat.

Happily, Buckland published a picture of Puddles watching for his beloved "dogs," which is here reproduced (Fig. 4).

Last of the European examples is a somewhat detailed account of the exploits of a fisherman cat in Scotland. This is copied from a newspaper clipping of unknown source but dated 1928:

> A cat in Dumfriesshire has become famous as an expert fisher. Not far from her abode there is a ford on the river, across which stepping stones are placed. On one of these, when the water is low, puss takes up her position and keeps a steady outlook for small passing fish. She never alters her position, and any passing not within striking distance, she takes no notice of. When one passes her stone, she puts out her paw and secures her fish. Seldom the second paw is brought into action, unless it is a fair-sized fish, but she never enters the water, and only her paws are wet during her operations.

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FIG. 3. THE CAT AT THE GARDEN POOL

SINCE THE FISH REMAIN DEEP IN THE POOL, THE CAT TICKLES THE WATER TO ENTICE THEM WITHIN REACH.

She is well known to all the regular fishers, who often give her a small trout. She eats none of them by the riverside, but carries them all home first.

One day, lately, a fisher was having lunch about 50 yards below the ford, when a splash arrested his attention. On looking around, he discovered that the cat was in the water, and being dragged down in deep water. It was quite evident that the cat had its claws fixed in something. Sometimes she would be completely submerged and then [would] rise to the surface. This continued for some distance till the cat struck a shallow part of the stream and regained her footing. It was then seen that she had her claws in a trout of considerable size. Puss looked half her usual size as she looked round about studying her position how to regain dry land. This did not take her long, and, catching the fish in her mouth, she went the same way as she entered.

Fishing Feats of American House Cats. A number of published accounts of incidents of fishing by American house cats have come to hand. Only two have enough detail to be given here.

First, George Dimmock, writing in the *American Naturalist* in 1884, tells of seeing a manx (or so-called tailless) cat that often brought home ordinary fishes and even eels, which it had captured in the shallow water of the tailrace of a sawmill when the mill was shut down. Since domestic cats have long been accustomed to eat cooked food, though their ancestors ate fresh-caught animals, Dimmock doubted if domestic cats would eat fresh fish. Had he watched his cat, however, or known the literature, he would have found out that they are very fond of and do eat fresh fishes, even as they eat just-caught birds.

The second narrative is contained in a United Press dispatch from Providence, R. I., printed in the *New York Sun* of January 22, 1931. It is as follows:

It's not strange for a bird to catch fish, or for a cat to catch birds, but it's a bit unusual for a cat to dive into the ocean to catch fish.

Such a cat has Captain Adolph H. Aronson, keeper

of Pomham Light. The cat, called Tommy, acquired the fishing habit from Captain Aronson's children.

Perched motionless on a rock, Tommy awaits the approach of a fish, then dives head first into the sea, seizing his prey with mouth and claws. Tommy invariably hides the fish under a lilac bush on the island until he has enough for a meal.

A number of unpublished accounts of fishing by domestic cats, contributed by persons well known to me, are at hand.

A friend, now living in New York City, when a boy, used to spend part of his vacations at his grandparents' home in Washington County, N. Y. Here water was piped from a spring on a nearby hill to the farmhouse kitchen, the overflow running into a large trough alongside the back porch.

In a brook near the house were many young catfish 3 or 4 inches long. The boy used to catch some of these and place them in the trough where he could feed them and watch them play. The old house cat would perch on the edge of the trough and also watch them play—but with an ulterior motive, for, when a fishlet came within reach, the fish-hungry feline would hook it out with a paw and carry it away for herself or her kittens to eat. This performance the boy saw at various times on his vacations, and he was kept busy supplying the old cat with young catfish.

Dr. R. C. Murphy, of the American Museum of Natural History, writes:

During several summers close to 1900, when I was about twelve years old, I observed a family or group of swimming and fish-catching cats. They belonged to Captain Adolphus Davis, a retired shipmaster who had built a residence and outbuildings on property known as the "Island" at Mount Sinai, Long Island, N. Y. The dry land was really a flat mount, about an acre in extent, lying in a salt meadow and largely surrounded by tidal creeks.

The cats, of which there were always six or more, regularly hooked out mummichogs (*Fundulus*) with their claws from small sandy depressions that filled with each rising tide. Several of them had also so far overcome their aversion to water that they would swim across a thirty-foot creek. Captain Davis boasted that all his cats were amphibious. I frequently saw one of them in the act of swimming across the creek.

Dr. Libbie Hyman, also of the American

FIG. 4. "PUDDLES" LOOKING FOR HIS BELOVED "DOGS"
"MOST SUPERBEST CAT AS EVER WAS AFLOAT." FROM BUCKLAND'S *Curiosities of Natural History* (1891).

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FIG. 5. THE CAT CATCHES HIS FISH

FROM ROCKS ALONGSHORE THE CAT HAS GRAPPLED A FAIR-SIZED FISH, JUDGED BY THE STIR IN THE WATER.

Museum, has communicated the following interesting observation:

Some years ago while working at the marine biological station at Friday Harbor, San Juan Island, Wash., I frequently saw the large male cat belonging to the mess hall of the laboratory, engaged in fishing. He would park himself on the rocks at the water's edge, where he could look down and see the fishes, and, whenever a small fish came within reach, he would scoop it out with a paw. He was never observed to go in "all over." The fishes were eaten on the shore as soon as caught. The fishing proclivities of this cat were well known, particularly to the kitchen staff, which was on duty the year round.

Doctor Hyman has no picture of this cat in the act of fishing, but I have found a photograph that seems to have been made of just such a fishing (Fig. 5). The fine gray cat shown has just made a pass at a fish. From the commotion in the water, it appears to have driven its claws into an actively resistant fish, but the end can be easily foretold.

Dr. Lolabel Hall, of Brooklyn, communicates this account of a favorite cat:

Quintus, a large yellow male cat, was a great family pet, and as such it was taken each summer for many years to my camp on Little Lake Ossipee, near North Waterboro, Maine. The house was situated about 30 feet back of the high bank of the lake, and as soon as Quintus was let out of his basket he would make a beeline for the lake and out on the little pier whence he could see the fishes, frogs, and turtles swimming by.

When the water was low enough, Quintus was accustomed to go down to and patrol the water's edge, where he would watch the fishes (minnows, sun perch, catfish, and pickerel) swimming close to the shore. The fishes were accustomed to being fed from the little pier and were quite tame. When they heard any splash at the pier they would come in considerable numbers and would swim about near the pier. This performance would excite Quintus greatly. And although he hated to get wet, he would stand at the water's edge and advance a paw into the water, trying to catch one of these semitame fishes—which always kept just out of his reach. Then he would go in until half immersed, but I never saw him reach the prey. He dearly loved to go out in the boat and would sit in the bow and vigilantly watch the fishes. While these would greatly excite him, he never went overboard after them.

The turtles were even tamer than the fishes and would take food from our fingers. They would also crawl out on the beach to bask in the sunshine. Here Quintus would (gingerly) play with them. Once I caught him at this and tried to photograph him in

the act, but the negative was not sharp and clear. Once he caught a frog and tried to eat it, but his mouth was made so sore that he never tried it again.

He was never seen to catch a fish, but judged from his persistent watch along the shore for ten summers he must have done so. Perhaps one reason why he was never seen with a fish was that the wide porch of the camp, on which we spent most of our time, was about 20 feet from the bank which fell away steeply to the water. Indeed, one could not see the narrow shore unless one stood almost at the edge of the bank. However, the constant behavior of the cat leads strongly to a belief in his fish-catching. This is accentuated by his constant catching of birds in our yard in Brooklyn and of baby squirrels that lived in the attic of our house.

The foregoing accounts are all that have come to hand recently of ordinary fishing by cats—by standing on the bank of a stream, on an overhanging rock or log, or in the water and hooking out the fishes with a thorn-filled paw; by wading in shallow water; or by going in all over in deeper water and catching the fish with paw or mouth as they swim past. These accounts are so widespread in time and space that, apart from the fact that a number of the reporters are known to me personally, they definitely establish the fact that house cats in their "violent fondness for fishes" do go afishing.

However, there have also come to hand three accounts of such unusual modifications of this hooking-out of fishes by domestic cats that they deserve to be treated separately, each under its own heading.

The Tongue as a Lure. After reading my article on "Cats as Fishermen" (*Natural History*, 1925), Mr. Seth Lindahl, of Chicago, sent me the following interesting variant of the ordinary fishing cat procedure:

In my backyard I have a pond that is visible from the breakfast room. And while sitting there one morning I noticed a cat crouching on an overhanging rock and to all appearance drinking from the pool. However, his lapping continued so long that it aroused my curiosity, and I went out on the rear porch where I got a closer view of him. He was not drinking but was simply wagging his tongue in the water. This continued for about fifteen minutes when he was frightened away.

From the position of his right paw and his steady gaze toward the fish playing around a lily pad close by, I can draw no other conclusion than that he was using his tongue as a lure, expecting that a goldfish would come close enough for him to hook it out with his paw.

This interpretation seems entirely reasonable to me. There would seem to be little doubt that this matter was begun by the cat lapping up water with its tongue for drinking. It is well known that goldfish are attracted to the surface of the water by slight disturbances. There they could be scooped out by a cat's paw. The cat, being intelligent, would quickly learn to trick the fish, and in this way a habit would presently be formed. It is to be regretted that no further observations were made and, especially, that no photograph was obtained.

Shining Eyes as Lures at Night. And now comes an account of cats catching fishes at night from an outdoor pool. It is recorded by Neill Rhodes, of Jacksonville, Fla., in *The Aquarium* (September, 1935). The *modus operandi* of the cats was so unusual that the writer will be quoted verbatim. The disappearance of fish from his pool had been so frequent and so great as to lead to the suspicion that night trapping or seining had been done. Consequently the pool was watched. Then:

After we transferred our Black Mollies to outside pools this spring, I noticed one night that two cats had located themselves at the sloping end of one pool, and that something in the pool had their attention about as much as their usual prey, the mouse. There being a little light reflection, I noticed the water surface was in a ripple in front of these cats. Watching this situation closely for a few minutes, I soon discovered why our loss had been so heavy in this particular pool. I noticed that these cats would lower their heads almost to the water's level with their eyes sparkling and, with unusual speed, a cat would strike the water with a paw and run away, soon returning for a repeated Black Molly knockout.

Mr. Rhodes states that he has been a hunter and trapper and has long had knowledge of how night prowlers see their way about in the dark, and while hunting he has observed many a pair of fiery eyes on dark nights. Hence, noticing that there was some light reflected from the water of his pond and that the fish swam up to the cats, he concludes that the fish were attracted by the shining eyes of the cats and came up to investigate—with fatal results to themselves.

This idea is based on the well-known fact that a deer will be dazzled by a light on a hunter's hat. Also, one authority has written that "the jaguar's eyes shine at night

like balls of fire." And various writers have stated that the eyes of the house cat shine at night and sometimes "give off a brilliant light." But if these eyes shine in the night, it can only be because light is reflected from the eyeballs of the cats. The eyes of these animals do not have any light-giving powers. They are reflectors only.

It is well known that fishes are attracted by lights. The use of lights as lures has been practiced by fishermen for hundreds of years. If Mr. Rhodes's cats were sitting on the edge of the pool facing the west *early* in the evening, there might still have been enough light reflected from the water to "shine" the cat's eyes. Or, if the moon were shining and the cats were facing the moon, the light reflected from the water might have illuminated the eyes of the cat. Now it is also well known that the pupils of cats' eyes are capable of great distension at night. This gives their eyes the power to focus more poor light rays on the retina and thus to see in the dark. The fish, attracted by these shining eyes, might have moved up near enough for the cats to have seen them in the semidarkness and to have snatched them out with a swing of the paw.

The Tail as a Lure. Mr. Carl Spencer, of Spencer, N. C., operates a copyrighted service called "Odd Facts in Carolina" in the Sunday issues of a number of North Carolina papers. This consists of drawings and their accompanying captions after the fashion of Ripley's "Believe It or Not." In the Sunday editions of July 12, 1942, appeared the figure of a house cat fishing with its tail in a garden pool. Through Mr. Spencer's courtesy this illustration is reproduced herein from his original drawing (Fig. 6).

Immediately after seeing the newspaper reproductions of this drawing I wrote to W. G. Heavner, of Newton, N. C., whose fish pool was being devastated. He courteously replied as follows:

> I have in my backyard a circular cement pool about 7 feet in diameter and 20 inches deep. At one point in the rim a couple of stones were set in the wall about 2 inches above the water level. On this shelf I had planned to place a dummy frog. To this pool, with its constant supply of water, all the neighbors' cats and dogs would come to drink. Sometimes one of these would sit on the projection while drinking. This pool was heavily stocked with goldfish, but presently these began to disappear. My five-year-old grandchild told me that she had seen a large gray tomcat, which belonged to a neighbor, catching the fish in my pool. It was hard for me to believe this until I caught him in the act. This cat apparently learned that the fish would come up when the water was disturbed. So it got to sitting on the rock projection with its tail in the water and would wiggle it to attract the fishes; and, when they would come up to see what was happening, it would snatch one out. It would not eat the fish on the spot but would carry it home to my neighbor's first.

Before my letter reached Mr. Heavner an attempt had been made to kill the cat to prevent further raids on the goldfish. This was not successful, but it apparently so scared the cat that it never came back to the pool. Considered from the standpoint of our study of animal behavior, this was most unfortunate, since it made impossible any further observations and, what is much worse, prevented the taking of photographs showing the cat in action. Such a photograph would be priceless in establishing visually this curious and most interesting feline behavior.

FIG. 6. THE TAIL OF A WISE CAT
DRAWING BY COURTESY OF MR. CARL SPENCER, 1942.

Certain things need to be considered in endeavoring to explain this incident. Goldfish are attracted by anything serving to disturb the surface of the water ever so slightly. They will come up not only for bits of food but also for bits of paper or any small debris, or in response to the tickling of the surface of the water by a twig. So much for the fish. The cat, on the other hand, is a very

intelligent animal, as all of us know and as the animal behaviorists have proved with their mazes, their trapdoors, and other experimental paraphernalia. The cat's tail is its most expressive member. (Witness its twitching as the cat watches a mouse hole.) The cat comes to the little platform to drink. The lapping attracts the fish, but they stay out of reach. The cat sees this much-loved food just out of reach and in eagerness and hunger twitches its tail and touches the water. The fish rush up to investigate, and one falls a victim to a swift stroke of the cat's paw. Finding it this easy to obtain its favorite food, how long would it take this observant animal to form such a fishing habit?

This alleged use of the tail of a cat as a lure in fishing will be considered more fully in a future article on such behavior by the jaguar of South America.

THE CAT*

When Noah beached on Ararat,
He found that he had saved a cat
(Or rather two) from where the Flood
Had left the earth submerged in mud.
In getting up his list he'd winked
And tried to make the cat extinct,
Because he knew, and knew full well,
Its tendency for raising hell.
But somehow, in the rainy dark,
Two cats had sneaked aboard the Ark
And had triumphantly survived,
Malicious, sly, and many-lived.
"Ah, well," said Noah, "that is that"—
And put a curse upon the cat,
A complex, triple-jointed curse
That can't be reproduced in verse.

So that is why the cat will play
And frisk and frolic all the day,
And lie beside the fire and purr,
And let the children stroke its fur.
But it remembers, after dark,
The curse it heard on Noah's Ark,
And sings, in ecstasy of fright,
A hymn of hate throughout the night.

—STODDARD KING

WILDLIFE ZONES ACROSS CENTRAL CALIFORNIA

By WILLIAM T. SHAW

In one of the broad corridors of McLane Hall, the science building of Fresno State College, there is displayed a series of biological habitat groups that express in a unique manner the wildlife distribution of central California. The presentation is especially apt in showing the influence of altitude on the forms of animals and plants. Beginning with the wash of sea level, the series extends inland across the various mountain elevations, broad valleys, and near-deserts, depicting from west to east the varied animal and plant life, topography, and geological formations. The idea of the series originated in the work of the college class in taxidermy dealing with group making. The original plan for a single group was soon expanded, by suggestions of the late Dr. George W. Graves and by Professor A. E. Culbertson, and later became state-wide in its development.

The chief value that this direct line of cross-state habitat groups, or home areas of animals and plants, possesses is that it makes easy, by visual representation and carefully prepared scientific labeling, an understanding of the intriguing subject of life zones, which are laid before the observer in a progressive sequence. Because of sharp rises in altitude, such zones often exist prominently in rather concentrated areas, especially in mountainous countries, and are frequently perplexing to students of the outdoors. In flat countries, however, where there is little sudden rise in elevation, the zones are more easily understood.

For instance, if we were to journey northward at the Gulf of Mexico far across the United States and Canada into the Arctic, we would notice along the way a gradual change in animal and plant life. The forms observed at the Gulf would be replaced by other, newer kinds on the northward trail. These, in turn, would give way to other species, and so on until we reached the Arctic. The egret of the South would occur less and less until at last it would be seen no more, and in its place would gradually come to view another bird, likewise of snowy whiteness but of vastly different habitat—the Arctic grouse, or ptarmigan. Normally these two birds are predestined not to meet, for each lives its life cycle in a homeland widely separated from that of the other. Naturalists call these regions life zones. Each zone has its characteristic fauna and flora. That of the egret has been given the name Austral, or Sonoran, Zone; that of the ptarmigan, Arctic Zone. So it is with other animals, and to a large extent with the plants associated with them; each is more or less definitely, although by no means absolutely, associated with one or more regions, or life zones, which students of biology have given names suitable to their geographic position. Accordingly, in our progressive journey north we meet in succession, after crossing the Sonoran Zone—the Transition, the Canadian, the Hudsonian, and finally the Arctic Zone, each with a few characteristic animals and plants found more or less constantly dwelling in them. Those forms holding most true to their habitat are known as zone indicators.

These biodivisions have proved of much use to the scientist, especially in the study of geographic distribution of animals and plants, migration, estivation, and hibernation. If, in our imaginary journey, we had traveled in another direction, the same or similar observations could have been made, as in many mountainous states and provinces in eastern and western North America and in South America. In a relatively shorter time and distance we might have noted similar life-zone phenomena by going from sea level to mountain ridges of 10,000 to 12,000 feet elevation, regions of perpetual snow and glacial ice.

The recently completed series of habitat groups at Fresno attempts to explain the sequence of these changes of biological habitat brought about by such influences as altitude, season, temperature, and climate in central California. In the demonstration five life zones are clearly shown, beginning

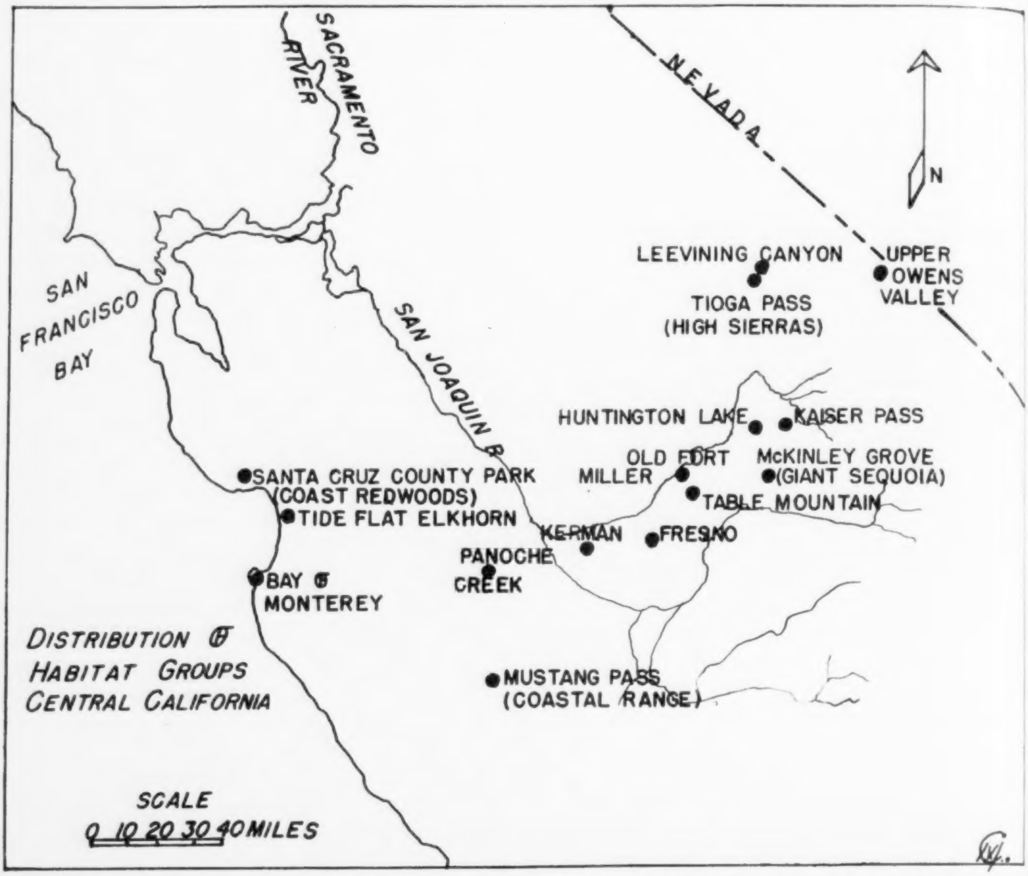

FIG. 1. DISTRIBUTION OF HABITAT GROUPS ACROSS CENTRAL CALIFORNIA

at the Bay of Monterey and going east across the Coast Range Mountains, through the San Joaquin Valley, and continuing over the Sierra Nevada Ranges to the extreme eastern border of the State.

Dioramas they are called by the artists; habitat groups or just plain windows by the students. It is as if one were looking out of a streamlined overland express upon a landscape resplendent with dim-fading vistas. The "windows" are populated with the life of the land they represent—with bird and mammal forms and simulated plant types typifying the life zones from which they came, all properly spaced and balanced as to numbers of species. The foregrounds of the habitats are built with samples of rock material and sand from their own wild heath or cliff side. The backgrounds of soft pastel tones, enhanced by varicolored neon illumination, easily lead the observer far into the land of pleasant contemplation—back into those dim memories of all-but-forgotten summers. These are the much-prized habitat groups, depicting this trans-section of colorful central California (Fig. 1), extending in ever-changing view from bold reefs and white-crested spray of ocean line, over mountain ranges and gray desert valleys, to the bordering serrated snow mountains of the far Nevada line.

First, as if with interested pleasure, Old Monterey presents itself with its restless inhabitants and the shifting colors of the sea (Fig. 2). Close-up are laid the reef rocks of brown and gray and the slippery, water-laid thalli of kelp glistening like wet rubber, stranded by exhausted waves of out-tide, soon to be tossed again by noisy oversurging swells of an ever-returning sea. Monterey cypress, rare and famed, lends a strip of strong fresh green to the shore line in this

cooled and tempered Transition Zone. Far beyond low-tide line are jutting rocks of the Bay, where strange pelicans and stranger cormorants have come to rest. Against the sky are buoyant, light-bodied gulls, drifting here and there on erratic, varying air currents. Across the sky the sanderlings line by, in swift synchronized flight. The California clapper rail stalks among the brown boulders of the coves, scarcely different from them in its quiet tones, yet strangely separated from its summer home in the marshes. Black turnstones, wearing the somber hues of rocky pools and the white of foam-dashed wave tips, industriously search out young, cap-shelled limpets. These are the birds of the sea, slightly suggestive of those of the great shore line.

But not all shore lines are rugged, as those of Monterey. Some, still at the level of the sea, as at Elkhorn Tide Flats, also Transition Zone, have extensive fields of brackish bars and shoals, the feeding grounds of countless birds, chiefly of shorebird type, vastly populated in times of migration. Western willets, Hudsonian curlews, and yellowlegs are here, with flock upon flock of least sandpipers. These are the common birds of Elkhorn, for it is early spring and the migration is on.

Before leaving the salt water, on the eastward way, we must visit Santa Cruz County Park, where a worthy stand of stately coast redwoods (*Sequoia sempervirens*) is found, set aside for a future playground by the forethought of one who looked far into coming years and saw a spot destined to satisfy the esthetic desires of a nature-admiring people. Here stand those noble trees (Fig. 3), stately in size and towering height, yet far more sublimely impressive and worthy of our worship and reverence for the reason that they carry forward, from far back in the centuries of the past, that thing called life. The shade from these and the dimness cast by dense foliage of the broad-leaf maple and the limber-branched tanbark oak have made suitable homes for western robins and for such birds as the varied thrush and the Alaskan hermit thrush. Here, too, the bird of all the shade-loving birds, the western

FIG. 2. SEA LEVEL ON THE BAY OF MONTEREY: TRANSITION ZONE

HABITAT FOR SUCH BIRDS AS PELICANS, CORMORANTS, SANDERLINGS, TURNSTONES, AND RAILS—RESTING AND FEEDING AMONG THE REEF ROCKS AND SEA-TOSSED KELP. A STRIP OF MONTEREY CYPRESS LINES THE SHORE.

FIG. 3. *SEQUOIA SEMPERVIRENS*
THE REDWOOD, PRIZE TREE OF THE WORLD AND THE OLDEST LIVING THING. TRANSITION ZONE SPECIES.

winter wren, finds a home of its desire. A slight elevation above sea level has been reached here, but not so high as presently, in the mountain passes of the Coast Ranges. The zone is still Transitional.

Perhaps one of the most inviting vistas of all this trans-section series is shown next (Fig. 4), illustrating the range of soft-toned pastel in depicting far-away scenes. The eye carries us back to the distant western ocean country from which we just came, as we look through this diorama in Mustang Pass, 3,000 feet above the sea—high pathway through the Coast Range Mountains. The life zone is Upper Sonoran, implying warmth. The season is early autumn. The landscape is well seared by the heat of past summer days. Green vegetation is largely gone. The blue oak is the most picturesque tree, seasonally destitute of leaves, with its innumerable twig tips bristling and its plain gray bark blending with the drabness of much of the scene. It is the tree generally sought by many small birds, such as Nuttall's woodpecker, juncos, and kinglets—a veritable happy hunting range for small sharp eyes and snapping, prying beaks. A great part of the beauty of the landscape, especially at this time of year, is due to the outcropping of rugged patches of lichen-tinted rocks scattered here and there on the grayish hillsides. Associated with these outcrops appear clumps of juniper, in some instances showing signs of having been severely wind-swept by persistent wintry gales from the far-distant ocean. In more sheltered spots these picturesque trees have an abundance of clear green foliage, adding a touch of interest to the life of an otherwise parched landscape. Dispersed over the semiarid hills stands the Spanish bayonet, adding to the harshness of the scene. The gorgeous blossom of this desert yucca has passed long since, and there remains only the tall bleached pole, which in springtime bore the showy white flowers. After studying the faunal arrangement of this habitat group, one would be apt to decide that the most conspicuous and unique bird of this area would be the yellow-billed magpie, as it glides across the landscape in steady flight, so suggestive of a distant airplane. Fine opportunity is given here for contrasting the two members of the dove family, common to western California, the mourning dove and the band-tailed pigeon. As might be expected, in a rugged rock outcropping, the yellow wood rat, or pack rat, is found; this little rodent is here shown beside its nest of foregathered twigs and sticks, low down in a rocky crevice.

So far in our dioramic cross-state journey we have been dealing with diurnal life, that which prefers to go by day. To accommodate the night roamers, a nocturnal group has been introduced. The Coast Range Mountains and Mustang Pass are westward now, and a new and semiarid country has appeared; much of the marine mists and rains has been chilled to precipitation in the journey over the mountains, and as a result there has been produced a country greatly in contrast to that of the ocean front. A typical location is found and a habitat scene selected among the east-sloping foothills, at the junction of the Silver and Panoche Creeks (Fig. 5), where the latter is soon to join the assemblage of weird "lost rivers," as its waters

FIG. 4. UPPER SONORAN ZONE NEAR FRESNO
TYPICAL SPECIES OF THIS ROCKY TERRAIN ARE THE DIGGER PINE, BLUE OAK, YELLOW-BILLED MAGPIE, BLACK PHOEBE, KIT FOX, AND YELLOW WOOD RAT.

fade out in the sands of the thirsty desert to the east. Here at the confluence of these brackish streams is "staked out," as it were, this representative habitat group, toned by soft lights of the moon. To the left, threading westward, is a trail, which in pioneer days led the traveler from Fresno to the sea. Sheer vertical banks of silt mark the erosion of streams long since dried up. Bleak hills of rock and earth arise, cut from prehistoric ocean beds in whose waters long ago roamed and ravaged strange monster fish-lizards, the Plesiosaurs of the Cretaceous period. Here is a landscape of rare and desolate beauty when viewed in the ever-changing light of receding or returning day. Life in this Lower Sonoran Zone is perhaps not abundant in species, but it easily makes up for this scarcity by its unique ecological adaptations to the needs of its environment. Salt brush, gray and harsh, stands well spaced over the parched earth. At dawn raucous ravens complete the picture of desolation, while desert mammals—pocket gophers, pocket mice, and the dainty *Dipodomys* of the sage plains—all are here, harmoniously adapted to a habitat where to live must mean forever to strive, to save, and to hoard. Scarcely has the sun gone from out these plains in times of harvest, and darkness pressed silently in, when these Dipos, or kangaroo rats (Fig. 6)—some no bigger than a tiny mouse and others as large as a chipmunk or pine squirrel, and kangaroo-like in superficial anatomy and ways of locomotion —begin to garner their harvest of seed pods of peppergrass and "filaree." With tiny, nimble, swiftly moving fingers they pack them into ever-distending cheek pouches, presently placing their store in innumerable small, test-tube-like pits, an inch or so in depth, dug vertically into the top soil of their home den. Here their hoard is packed firmly and then covered with dust and left to dry. When, in the course of six or eight weeks, the seeds are thoroughly desiccated by the hot rays of the desert sun, they are transferred from the tiny pits to the depths of the animals' dens, forming caches of food for future needs. Such are the ways developed by the strange necessities of the desert. Such are the scenes now unfolding on this broad trans-state trail.

Now again, a lower level is reached, between the outstanding mountain ranges of the State. At Los Banos, elevation 104 feet, in the Lower, bordering the Upper, Sonoran

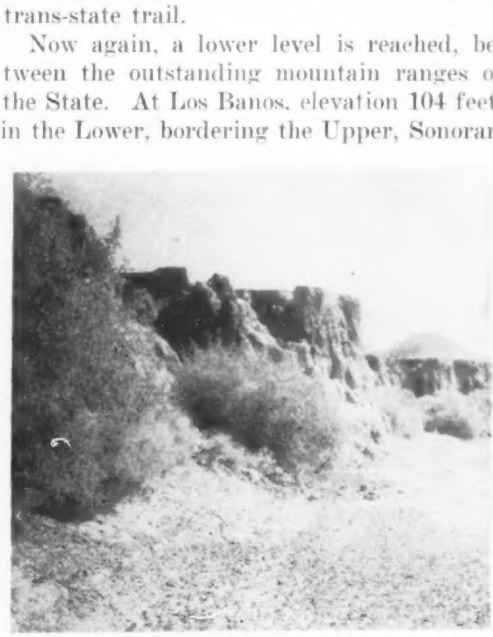

FIG. 5. LOWER SONORAN COUNTRY
NEAR JUNCTION OF SILVER AND PANOCHE CREEKS. SILT BANKS MARK EROSION OF ANCIENT STREAMS. HABITAT FOR MANY NOCTURNAL DESERT ANIMALS.

FIG. 6. GIANT KANGAROO RAT (*DIPODOMYS*)
THIS DENIZEN OF THE LOWER SONORAN ZONE STORES HIS FOOD IN UNDERGROUND GRANARIES IN HIS DEN.

Life Zone, there opens a wide area of overflow land, spreading an abundance of water during freshets from the San Joaquin River and producing a homey, marshlike haven for the wintering wildfowl, down from the Arctic. Especially prominent, on near and far-distant landscapes, is the American egret. The pools are populated with the avocet, the black-necked stilt, and the rare tree duck from Mexico way. The rushes have their lesser avian population. The San Diego redwing, with nest bound in (Fig. 7), the tricolored redwing and yellow-headed blackbirds, and Wilson's snipe attract attention from the areas of aquatic vegetation.

Presently, west of Kerman, elevation 215 feet, Lower Sonoran Life Zone, more of the semidesert is shown, with here and there patches of bitter alkaline soil and associated animal and plant life. Far-distant outlines of the Coast Range Mountains rise out of the west in the evening twilight, which has called out the little night-prowling mammals to their activities. The odd little grasshopper mouse, so called because it likes insects for food, the Fresno kangaroo rat, and the hoary, the brown, and the Mexican free-tailed bats are all here, each bent on its own private errand. Fresno itself, 300 feet above sea level, in the Lower Sonoran Life Zone, situated in a spot that was formerly a desert, has sprung into freshness, surrounded by sunny vineyards, thrifty alfalfa fields, and groves of olives, figs, and oranges. Birds of a home-loving nature, such as we like to have around lawns and gardens, are here. Bullock's oriole, the western meadowlark, the killdeer, the cedar waxwing, and the valley quail (Fig. 8) are prominent. The Fresno pocket gopher, discovered and first described here, is a mammalian representative of the group.

Eastward again the mountains are calling. The San Joaquin Valley is being passed; the fine, clear-watered river, which gives its name to the valley, is soon to be crossed. The foothills of the Sierra Nevadas are rising into rugged view.

In the San Joaquin River and Old Fort Miller Group (Fig. 9), similar in elevation and life zone to Fresno, lies much of historic interest—many reminders of those "first men" of '49. The old fort, represented in the background view, is now a thing of past days, having recently been submerged by the

FIG. 7. SAN DIEGO REDWING GROUP
THIS BLACKBIRD NESTS IN THE RUSHES OF THE WIDE LOS BANOS OVERFLOW LANDS, LOWER SONORAN ZONE.

FIG. 8. CALIFORNIA VALLEY QUAIL AND NEST

IT IS NOT UNCOMMON TO SEE FLOCKS OF THESE BIRDS ON SHELTERED LAWNS IN SUBURBS OF VALLEY CITIES.

waters stored above the nation's new Friant Dam. Here too is found a bird suggestive of pioneer days, Lewis's woodpecker, one of three birds taken back by Lewis and Clark from their journey to the Pacific in 1805. The wood duck, Anthony's green heron, and the California woodpecker, with his renowned acorn stores, also are represented. Beechey's ground squirrel, of current scientific interest as a possible spreader of the dread bubonic plague, is in evidence. The California weasel and the San Joaquin mole of subterranean habitat have found this region a favorable place in which to live.

Not far distant, at an elevation of 714 feet, in the Upper Sonoran Zone, is located the Table Mountain Basalt Area Habitat Group. This is of more than passing interest to the geologist, for here is shown, in the background, a great mesalike slab of basalt, representing a fine example of an extensive lava flow down the ancient San Joaquin River bed; now the deposit is left towering above the surrounding country by subsequent erosion of the softer supporting materials. Sheer basalt walls suggest the rock-inhabiting and cliff-nesting birds, such as the black phoebe and the canyon wren.

From the sea we have come, climbing up, down again, and crossing wide valleys. Now, progressing ever farther and higher into the great mountain system eastward, our attention is drawn to the strange tawny forms of isolated trees, so big and high as to make the stalwart trunks of the silver firs of the area look like saplings beside them. We stand speechless for the moment; the present slips silently away; we have awakened from a dream set in another age, long-passed centuries ago. With no thought of the morrow, we are content to linger in the cool shades of this ever-to-be-remembered twilight hour. In this McKinley Grove of Big Trees the giant sequoias (*Sequoia gigantea*) are stand-

ing clearly in the open, sunny Transition Zone at an elevation of 6,500 feet above the sea. Even before the sun's rays have glinted the tallest tips of the sequoias, morning hour is announced by the harsh notes of the crested jay. Also among the early risers is the California pine squirrel, even now aloft in the sunny crown of a great towering tree and warmly illuminated by golden morning sunshine (Fig. 10). His agile form, though tiny in the distance, is clearly discernible, as he nimbly darts about from branch to branch cutting the firm round cones and liberating them on their journey to the far-distant forest floor. This wise little forest harvester has sensed that cones of many pines, spruces, and firs, if not harvested in proper time and manner, will open their scales with warmth and dryness and scatter their seeds to the four corners of the wind. Because much of his food comes from the seeds of conifers, and because he has no cheek pouches in which to store wind-strewn seeds, their loss to him by the desiccation of the cones must be prevented; so he cuts the seed-bearing cones while they are still quite green and buries them in damp springy soil, or in moist shady places, where they remain with scales tightly closed for weeks, or even many months, ready for the stormy days of winter or the lean days of crop failure.

Here in McKinley Grove it is noticeable that the forest is thinning out and giving way to sunshine. The zone is typically Transition, which contains the main forest belt in this section of the Sierra Nevada. On warm slopes it extends from about 3,500 to 7,500 feet elevation and contains magnificent specimens of cone-bearing trees, with some deciduous forest.

At Huntington Lake–Rancheria Creek, 7,200 feet, the forest has opened out to the blue of the skies on the ridges, yet possesses densely shading trees and brush-covered walls in the snow-holding canyons. Here is first found the trembling aspen (*Populus*

FIG. 9. ALONG THE HISTORIC SAN JOAQUIN RIVER

REPRESENTING ANOTHER LOWER SONORAN HABITAT. WILDLIFE HERE INCLUDES BEECHEY'S GROUND SQUIRREL AND THE CALIFORNIA AND LEWIS'S WOODPECKERS. ALONG THE RIVER BANKS WILLOWS GROW ABUNDANTLY.

FIG. 10. SIERRA NEVADA PINE SQUIRREL
THIS AGILE LITTLE RODENT IS SHOWN STORING A CACHE OF GIANT SEQUOIA CONES IN A MOIST SPRINGHEAD.

tremuloides), an indicator of the Canadian Life Zone, which heretofore has not been encountered on the journey—a tree common in northern Saskatchewan at far lower elevation. Here too the red fir comes in to replace the silver fir of the Transition Zone. In this nocturnal habitat group is found the Sierra flying squirrel, soft-furred and so pronouncedly nocturnal that it is not commonly seen by man unless disturbed from its nest by day. It is clan to a southern race of a group of mammals ranging far north even into Alaska and Labrador. Among other forms found here is the mountain beaver, standing beside its tunneled home in the banks of brooks or springy hillsides; quite nocturnal, it harvests green vegetation during the nighttime to be placed advantageously for drying by midday sun. The cacomistle, or ring-tailed cat, is awake and ready for his evening prowling.

How sharply the trail rises now, in anticipation of the high divide outlined in the distant crags and gray granite boulders. Such is the approach to Kaiser Pass and Meadows, at 9,200 feet. Canadian Zone, merging into Hudsonian Zone, is here, with its lodgepole pine and tawny-trunked juniper standing sturdily upon impoverished granite slopes. The ridges are well opened to the sky, and by night the stars are nowhere so bright as here. Perhaps on an early day in June, which is the beginning of spring here, the most impressive awakening life is the waxen marsh marigold, lush of leaf, delicately white of sepal, yellow of stamen, springing from oozy marshland by the side of lingering snow. Too, the meadows are now many times alive with whistling, scurrying Belding's ground squirrels, recalling in its name an early west-coast naturalist. The mountain bluebird balances jauntily upon lithe pussy-willow tips.

The greatest elevation of all the Coast-to-Nevada Series is reached at Tioga Pass, 10,000 feet above the sea, providing passage from Yosemite to the Upper Owens Valley (Fig. 11). The life zone is leading clearly

into the Hudsonian. The Pass is enjoying early springtime, although the calendar says May 30. Here, in the neighborhood of perpetual glacial ice, even hardy vegetation is slowly passing out of the scene. Mammal and bird life is becoming rare in numbers of species. A coyote presents a dark retreating form far over a snowfield, or a marmot may mount guard among the snow-based crags. The cry of the cony sounds strangely alone on the sunny, south-sloping rockslide. The conies are southern invaders of related species roaming widely over territory far to the north in America. In California they belong to the startlingly and ruggedly beautiful Hudsonian Zone. High, and still higher, has been the climb to attain it—the counterpart of that alpine Klondike land by the Yukon. But the American bird of unique habitat, the Dawson or Sierra Nevada rosy finch, is here, where it seems of necessity to retreat at nesting time. Indeed, the nest of the rosy finch, a race of several species and varieties in western North America, is sometimes found in rocky ledges entirely above vegetation. The first of these rare birds known to science was taken over a century ago in what is now the Province of Saskatchewan, yet so remote is their summer habitat that they have long remained one of North America's most inviting and interesting birds.

Often when the mountaineer wends high through silent mountain passes and comes into the low country beyond, it is with a sense of regret and disappointment that new views are encountered. Not so here, however, as we enter the satisfying Leevining Canyon, which soon opens out into sun-brightened walls of varying colors. Deep down among the aspen-fir, through narrowing flats and bars, winds a rushing stream of purest water. Tumbling boisterously and noisily past grassy banks, on and down, over round boulders, it is soon to spread out onto the upper levels of Owens Valley, 7,000 feet above the sea. Much of the gray-green of the receding slopes of the canyon sides is due to scattered clumps of pinyon pine, a single-leafed, large-seeded conifer, which in season furnishes food for the pinyon jay, as well as for man.

At 7,000 feet, again in the Transition Zone,

FIG. 11. TIOGA PASS, 10,000 FEET ABOVE THE SEA

PROVIDING ACCESS TO THE UPPER OWENS VALLEY FROM YOSEMITE. THE LIFE ZONE IN CANADIAN-HUDSONIAN. LODGEPOLE PINE AND JUNIPER, THE COYOTE AND CONY, AND THE SIERRA NEVADA ROSY FINCH ARE TYPICAL.

FIG. 12. UPPER OWENS VALLEY–WHITE MOUNTAIN HABITAT

UPPER SONORAN ZONE AT 5,400 FEET. THE CHARACTERISTIC PLANTS HERE ARE GREASEWOOD, PRICKLY-PEAR CACTUS, GOLDBUSH, AND SAGEBRUSH, WHICH FURNISH COVER FOR MANY DESERT-LOVING MAMMALS AND BIRDS.

the naturalist has not far to go before the trail gradually loses its steepness and winds over an ever-widening canyon mouth, presently reaching the larger valley, stretching on and on, beyond and across to the brilliant range of the White Mountains, which mark the eastern border of the State. Here the freshness of high mountain and dewy canyon gradually gives way to somber gray of the desert. Far across the desert waste rise the splendid peaks of this range, many of them 10,000 to 13,000 feet high, glistening now in the snows of high Hudsonian and Arctic altitudes.

At 5,400 feet again, having descended into the Upper Sonoran, we reach the chosen habitat of the Upper Owens Valley–White Mountain Group (Fig. 12). Harsh plants and shrubs of truly xerophytic nature abound—the brash, clustered greasewood, the prickly-pear or cholla cactus, the showy goldbush, and the sagebrush. Animal life too is toned in and adapted to conditions of the desert. Standing motionless here is the gray-sand-colored sage grouse; there the grotesque roadrunner, the silver-tongued sage thrasher, and the diminutive Brewer's sparrow with anxious concern over its shrub-located nest.

Journey's end is drawing on. Twilight pause of another day has come. Brief remembrances, with memories of other trails, carry us back, back to ocean lines with mewing gulls, to oak-covered slopes of lesser ranges, to desolate moonlit hills and their fragile, frugal harvesters of scattered desert seeds. Back to the sequoias, serene at the end of their centuries; then up, up to the home of the brave finches, nesters of the Arctic-Alpine realms. Standing in the gray desolate beauty of desert shadows, to us there come the lines—

> In spots like these it is we prize
> Our Memory, feel that she hath eyes.

OUR REVOLVING "ISLAND UNIVERSE" AND ITS SPIRALING COUNTERPARTS

By WILLIAM T. SKILLING

OUR earth is an infinitesimal part of a great whirlpool of stars called the galaxy, or Milky Way. Not only are the sun, moon, and planets of the solar system moving as a very small unit that drifts with the rotation of the galaxy, but all the visible constellations of the sky are so close to us that they, too, are our fellow travelers in one small part of this cosmic eddy. Only recently has the tremendous velocity of our galactic rotation been measured and found to be 170 miles a second, in the direction of the constellation Cygnus.

On account of the smoothness of our travel and the freedom from any sharp turns in our course we do not feel this motion any more than we do the lesser speed of the revolution of the earth about the sun at a mere $18\frac{1}{2}$ miles a second. It is not the motion but abrupt changes in motion that we feel when riding in an automobile or train, and the earth makes no such changes in speed. The curve that the earth follows in its motion about the sun, 93,000,000 miles away, is so gradual that in each second the earth departs only one-ninth of an inch from a straight line while going forward $18\frac{1}{2}$ miles. Only by observing other moving bodies and the so-called "fixed stars" are we able to measure or even perceive our annual motion, and it is little wonder that astronomers have been slow in observing the vaster sweep of the whole solar system and its relatively near neighbors around a center that is two billion times as far away as the sun.

Soon after the beginning of this century the great Dutch astronomer Kapteyn, as a result of his studies in his native Holland, announced the discovery of two "star streams" flowing in particular directions. It has long been known that stars have *some* motion with respect to one another. But this previously known star motion, including that of the sun, was looked upon as being wholly at random. Kapteyn was the first to show any systematic drifts of great numbers of stars in any particular direction.

Gustaf Strömberg, at the Mount Wilson Observatory, examined the motions of various classes of stars and uncovered some surprising facts. His analysis of the motions of certain stars that the spectroscope showed to have very high velocities, fifty miles a second and up, proved that their directions are by no means at random. They seem to be leaving a particular part of the sky because the sun and its planets are moving toward that region.

The most rapidly moving stars, Strömberg found, are those far distant groups, each consisting of many thousands of closely associated stars, which are called "globular clusters." There are about a hundred of these clusters.

Thus, these and other men were finding beads of knowledge that eventually had to be strung together to show their relationship. The first to do this was Bertil Lindblad, of the Swedish observatory at Stockholm. He explained the apparent motion of high-velocity stars by fitting them into a theory of galactic rotation. He showed that if we assume the whole Milky Way system of stars to be revolving, then what otherwise appear to be peculiar and unaccountable motions of stars become natural consequences of that revolution. He likened our system of a billion or more stars to the spiral nebulae that can be seen far beyond the limits of the Milky Way and suggested that each of these nebulae is itself a distant island galaxy, seen as a blur of light because we are unable to distinguish any but the brightest individuals among its millions or billions of component stars.

Lindblad's suggestion was not new, but he was the first to form a complete theory. As far back as the time of Sir William Herschel our system of stars was being likened to the spiral nebulae. Herschel, with the large telescope that his patron George III had enabled him to build, could see many hazy patches of light that he shrewdly guessed might be star systems. The name "island universes," ap-

plied to these suppositional galaxies, became common at that time.

Herschel's telescopes were not powerful enough to resolve these nebulous objects into separate stars, but he predicted that all such clouds might one day be shown to consist of stars. With his largest telescope he had already proved that some objects which his smaller instruments showed only as glowing spots were really star clusters. What could be more natural than that with means more abundant, even, than those supplied by King George, telescopes might be made that would break up into stars even the most distant spots on the sky?

This very reasonable guess of Herschel's has since been found to be partly at fault, for the spectroscope, of more modern times, shows indisputably that some of the nebulae are gaseous and that some are made of gas and dust clouds mixed. But both the spectroscope and the modern telescope give evidence that many others are, as Herschel suspected, composed of stars. In addition, more recent knowledge of their distances shows that gaseous nebulae or those composed of illuminated dust clouds are within our own stellar system whereas those that are composed of stars are outside of that system. Hubble calls them "extragalactic nebulae" to distinguish them from true nebulae. Shapley, of the Harvard College Observatory, calls them simply "galaxies." This word indicates their likeness to the stellar system but does not distinguish them from it as the prefix "extra" does.

The name by which these outside galaxies are popularly known is "spiral nebulae." Both parts of this name are in error for some do not have the spiral form and none of them are mere clouds, which "nebulae" implies. Nevertheless, a spiral form is the most striking characteristic of those that do possess it. The name "island universes" pretty well suggests their nature, but it violates the usual meaning of the word "universe." Thus all names of these outside star systems seem to be open to criticism.

But what evidence exists to support Lindblad's theory that our galaxy is one of these spiral nebulae? First, there is the evidence deduced from their distances.

The spiral nebulae lie at such great distances that the surveyor's parallax method used for nearer stars fails utterly to give any idea of their location. However, their distances had to be known, at least approximately, before it could be definitely decided whether they are separate systems beyond our stars or only outlying parts of our galaxy. Happily an exceedingly powerful indirect means of measurement was discovered by which Hubble, of the Mount Wilson Observatory, learned that the distance to a spiral in the constellation Triangulum is about three-quarters of a million light years. Another still more conspicuous one in Andromeda was found to be at practically the same distance.

The method employed by Hubble makes use of a certain kind of star known as a "Cepheid Variable," a number of which had been discovered in the spirals. These stars are exceptionally bright intrinsically and can be seen at a great distance. As far away as these variable stars can be clearly seen their distances can be calculated, for their period of change from maximum brightness to maximum again is a key to their real brightness, and this, in turn, is a key to their distance.

A curve can be drawn (from Table I, for example) showing the relation between period and brightness, and from the curve the actual luminosity of a star of any period can be found. Then by simply comparing this real brightness with the brightness that the star seems to have, as measured with a photometer, the star's distance can be found. (If there is obscuring matter between us and the star its dimming effect must be found and allowed for before the comparison of real and apparent brightness is made.)

TABLE I

BRIGHTNESS OF CEPHEID VARIABLES OF DIFFERENT PERIODS

Period in days	Number of times brighter than sun
$2\frac{1}{2}$	350
5	550
10	830
20	1500
40	2500

The two nearest of the spiral nebulae were in this way found to be so distant as to be well separated from the outermost stars of our galaxy. The estimated distance from side to side of the Milky Way system is about 100,000 light years. Seven or eight such systems could be laid side by side in empty space between our stars and those of the great nebula in Andromeda, one of our two nearest neighbors, before the gap would be bridged.

A second point of similarity between our galaxy and the spiral nebulae is size. The sizes of extragalactic nebulae, as found from their angular diameters and distances, approach nearly enough the size of the stellar system to warrant their being classed with it rather than with even the largest of our own star clusters or star clouds, such as are seen along the Milky Way.

Third, the similarity of our star system and the spiral nebulae is shown in the flattened shape of each (Fig. 1). Herschel, with unlimited patience, counted stars in all directions and found that the stellar system is "shaped like a grindstone," to use his own comparison. More recent counts amplify Herschel's discovery by showing that the sun and the solar system are not centrally situated in our galaxy. To the naked eye or with a small telescope there seem to be about as many stars in one direction as in another in the plane of the Milky Way, but with a telescope that will penetrate to greater depths many more stars can be seen in the direction of Sagittarius than in that of Auriga. The

Courtesy of the Mount Wilson Observatory

FIG. 1. THE SPIRAL NEBULA H V 19 IN ANDROMEDA

DOUBTLESS OUR GALAXY WOULD RESEMBLE THIS NEBULA IF SEEN EDGE ON FROM A GREAT DISTANCE. THE DARK CENTRAL LINE IS CAUSED BY DUST IN THE PLANE OF THE NEBULA AND CORRESPONDS TO THE DARK RIFTS IN OUR MILKY WAY. THE INDIVIDUAL STARS ARE IN THE FOREGROUND—WITHIN OUR GALAXY.

reason is that we are far out from the center in Sagittarius toward the "anticenter" (the point opposite the center) near Auriga. Measurements of a different kind place us about two thirds of the way from the center to the circumference. But still we are nearly in the plane of the Milky Way.

Finally, the motion of our galaxy is similar to the motion of the spiral nebulae. It is now definitely known that the spirals are rotating. For this belief is there not strong presumptive evidence in the appearance of the spiral nebulae? There seems little doubt that they have acquired their flattened pinwheel appearance (Fig. 2) from rotation about a center, for a group of stars would in time collapse to their common center if it were not for the centrifugal effect of motion that counterbalances the inward pull of gravitation. If this appearance were not sufficient proof of the rotation of the spirals, there are spectroscopic observations to show it. V. M. Slipher, at the Flagstaff Observatory, and more recently Dr. Hubble, at the Mount Wilson Observatory, have used the spectroscope upon nebulae in much the same way it is used in measuring the velocity of rotation of a planet. Using spiral nebulae that do not have their flat side directly toward us, the slit of the instrument was set as nearly as could be upon the equator of the spiral, perpendicular to the axis of rotation. The resulting spectral lines slant because of the approach of one side of the light source

Courtesy of the Mount Wilson Observatory

FIG. 2. THE SPIRAL NEBULA M 33 IN TRIANGULUM

OUR GALAXY WOULD PROBABLY RESEMBLE THIS NEBULA IF WE COULD SEE IT FROM THE OUTSIDE NEARLY FLAT SIDE ON. ITS PLANE IS TILTED 33° TO THE LINE OF SIGHT, AND SO IT HAS BEEN POSSIBLE FOR ASTRONOMERS TO MEASURE WITH THE SPECTROSCOPE THE ROTATIONAL SPEED OF MANY OF ITS POINTS OF CONDENSATION. THE NEBULA ROTATES AS IF IT WERE A SOLID FROM THE CENTER HALF WAY OUT TO THE EDGE, AFTER WHICH SPEED FALLS OFF. ITS MAXIMUM SPEED OF TURNING IS ABOUT 75 MILES A SECOND, AND THE WHOLE NEBULA APPROACHES US AT ABOUT 100 MILES A SECOND. DIRECTION OF ROTATION IS CLOCKWISE.

and the recession of the other side. Slipher and Hubble agree that there is motion in the direction we should expect; most of the material of the nebula is at the more condensed central part, and as this turns, the two arms projecting from its opposite sides are left trailing behind.

At our great distance from the spirals the angular motion is too slow to be observed with certainty on direct photographs of the nebulae, even with pictures taken several years apart. Perhaps photographs of the next century when compared with those taken by this generation of astronomers may show changes in the position of stars of these galaxies.

There can be no question as to the rotation of spiral nebulae; what, then, is the evidence that our system of stars is like them? Some of the extragalactic nebulae that are not spiral show no sign of motion. If our galaxy turns, how would the motion of its stars be observed to show whether or not they are revolving about a common center? Lindblad was unable to make any direct measurement of our galactic rotation. The position of the earth within the galaxy is an unfavorable one for observation of its rotation. So Lindblad's approach to the problem was to explain, in so far as possible, all observed motions of the stars of the galaxy (as they appear to move with reference to our sun) in terms of a great rotation.

Lindblad interpreted the apparent motion of the so-called "high-velocity stars" as being caused by our more rapid rate as we and they revolve, all in the same direction, around the center of the stellar system. These slow "high-velocity stars" seem to be headed backwards with respect to the true direction of all the stars. They seem rapid because they lag behind so rapidly.

But why would not stars equally distant from the center of the galaxy all move equally fast? For comparison, it is well known that a comet travels very slowly while going around the end of its long elliptical orbit that is farthest from the sun. Then it gains great speed through years spent in falling closer. Halley's comet, for example, went about 35 times as fast in 1910, when it was making the quick swing around its "perihelion," as it is moving now, during the 1940 and 1950 decades, when it is out beyond the orbit of Neptune. As the comet falls back toward the sun it will regain its speed. Even the earth, which has an orbit nearly but not quite circular, goes faster in December than in June because it is then 3 per cent nearer the central sun. It is partly due to this greater velocity of the earth that winters in the northern hemisphere are a week shorter than summers. If their orbits were exactly circular around the sun, all bodies at equal distances from it would go at the same velocity, whether they were planets, comets, baseballs, or grains of sand. Stars would behave in the same way in going around their attracting center.

In the great rotation of our galaxy most star orbits around the common center are nearly circular, and therefore any two stars fairly close together, say within a hundred light years of each ~~other~~, move at nearly the same velocity. The sun is a typical star and has a nearly circular orbit. The difference between the velocity the sun actually has and what it would have if its orbit were exactly circular is found by comparing its motion with the average for all stars in its vicinity. This variation from the average velocity is called "solar motion." It is 12 miles a second, as was found by several observers. The variation of the rate of any star from the velocity it would have if its orbit were circular can be similarly found. These variations in the velocities of stars caused by differences in the shapes of their orbits are often spoken of as their "peculiar motions," to distinguish them from the variations in velocities caused by differences in distance from the center of the galaxy.

Although an occasional star is found to have a velocity with respect to the sun greater than 50 miles a second, it is never going in the direction of the sun's revolution around the galactic center. It is always a slow star that we are overtaking. No stars have been found that run as much faster than the sun as some of them run slower. The reason is that they would be thrown out of the galaxy by centrifugal effect if they did. Neighboring stars can go a little faster than the sun, but they cannot go *much* faster. If a star should pass us with a velocity as much as thirty or forty miles a

second greater than that of the sun, we could bid it farewell, for such a motion would carry it out of the stellar system beyond the gravitational control of the stars.

In this way the puzzling stream of "high speed stars" was explained by Lindblad in simple terms of gravitation. They are really low velocity stars at the slow end of eccentric orbits, and we, and other stars of fairly uniform speed, are overtaking and passing them. These eccentric stars will in time fall in toward the center, regaining speed, but now they are lagging badly behind.

And the extreme high speed of globular clusters of stars, as much as 170 miles a second, simply means that these clusters are not part of our galaxy at all, or at least do not rotate with it, and the observed velocity is really our own speed of travel with the galaxy as we go rapidly past the stationary clusters.

SOON after Lindblad's explanation of "high velocity" stars and other phenomena of stellar motion, a Dutch astronomer, Oort, developed a direct method of studying the rotation of the galaxy by using the velocities of many stars at known distances from us. He worked out a comparatively simple means of using such measurements to learn a great deal about the stellar system and our position in it. His plan of procedure has been used since then by a number of astronomers, who have applied it to various classes of stars. Notwithstanding the great difficulty of making the required measurements the different workers have arrived at very similar results.

Oort's plan is based on the fact that revolving bodies controlled by a central attractive force move at unequal speeds depending on differences in distances from the center (Fig. 3). The different velocities of planets revolving around the sun illustrate this. Pluto, the outermost planet known, travels at 3 miles a second; Jupiter, nearer the sun, at 8.1 miles; the earth at 18.5; and Mercury, nearest the sun, has an average speed of nearly 30 miles a second.

Our solar system of sun and planets has practically all its mass at the center; 99$\frac{6}{7}$ per cent of it resides in the sun, only $\frac{1}{7}$ of 1 per cent in the planets. Being so constituted, the rate of motion of a planet at any known distance from the center is very simply calculated by means of Kepler's great discovery of more than three hundred years ago, his law of "harmonic motion."

The rate of motion (and the period) of a star at any given distance from the center of the stellar system is not so easily found, for the mass of the system is more widely distributed. There is no great central star dominating all else. If the distribution of

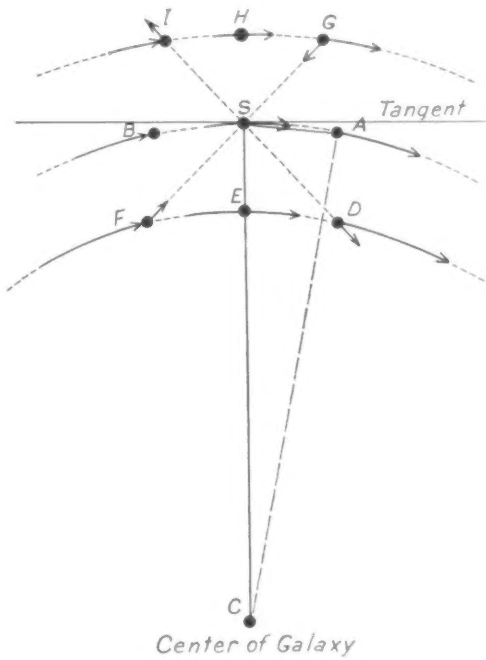

FIG. 3. INTRAGALACTIC VELOCITIES
SHOWING RELATIVE VELOCITIES OF SUN (S) AND STARS AROUND THE GALACTIC CENTER. SHORT ARROWS REPRESENT COMPONENTS OF MOTION OF STARS TOWARD OR FROM THE SUN, AS SHOWN BY THE STARS' SPECTRA.

material in the stellar system were quite uniform throughout, with no concentration of stars toward the center, the whole flattened Milky-Way system would rotate as a wheel, and we could detect no motion at all unless we could observe some outside landmarks, such as extragalactic nebulae, that do not revolve with the stars.

Actually, however, the stars of our galaxy are sufficiently concentrated near its center to give measurably different stellar velocities. Yet the galaxy is so large and the dif-

ference of velocity as seen from the earth so small that our greatest telescopes are needed to observe the relative motion; even with the largest telescopes we cannot observe individual stars of our system as far away as the center of the galaxy, and only with difficulty can star velocities be measured as far as one fourth the distance to the galactic center. Since Oort's method of detecting and computing the rotation of the stellar system depended upon measuring their relative motion, his work had to be based upon observations of the most distant observable stars. But even these are relatively close in terms of the dimensions of the galactic whirlpool.

Because the closest stars that can be used in obtaining data for Oort's method had to be more than a thousand light years distant from us, Plaskett and Pearce of the Dominion Observatory, Victoria, B. C., worked with those very hot and white giants of classes O and B. Rigel, lying at the foot of Orion, is one of these and is one of our brightest appearing stars, but being only about five hundred light years away is too close to be used in Oort's method. However, stars of this type can easily be seen at much greater distances with such a telescope as the one at Victoria.

Others have used those reddest of all stars, the N type, which average several hundred times the brightness of the sun. The so-called "planetary nebulae" are stars surrounded by gas, which makes them exceptionally luminous. The peculiar, brilliant gas, supposed to have been thrown out by some violent explosion long ago, can be seen at astonishing distances. But in some respects the best stars of all to show rotation of the galaxy are the Cepheid variables, the stars that gave distances to the spiral nebulae as mentioned above. Joy, at the Mount Wilson Observatory, has studied about a hundred and fifty of these, distributed mainly along the Milky Way. The results thus obtained are very dependable because of the unusually reliable manner, explained above, in which their distances can be determined.

Motions of these stars could theoretically be measured in two ways: by getting the angular distance they travel across the sky in a certain length of time—their "cross-motion"—or by finding the speed in miles a second by which they come closer to us or move farther away—"radial motion" or "motion in the line of sight." The spectroscope will measure this line-of-sight speed. The lines of the spectrum of an approaching or receding star are shifted a little toward the blue or the red end of the spectrum as a result of the motion. This is often called the "Doppler shift." The greater the speed of the star the greater the shift.

Cross-motion is not useful in studying galactic rotation, as many years must elapse between the taking of two photographs of the stars to show any appreciable change in their positions. But the spectrum of a star can be photographed in a few minutes (or hours, depending on its dimness) and the star's radial velocity is found immediately.

The general principle of Oort's method may be readily understood by considering the solar system. A planet, such as Venus, when nearest the earth and directly between us and the sun has cross-motion because it goes faster than the earth, but it has no radial motion that would be indicated by the spectroscope because it is keeping parallel to the earth's orbit and so is not changing its distance from the earth. Likewise Mars when nearest the earth on the opposite side from the sun is not changing its radial distance, although it has cross-motion because it moves slower than the earth.

If we assume another planet a little in advance of the earth, or behind it, in the same orbit, the hypothetical planet would show no radial motion. The spectroscope would show it as a stationary object. But in all other directions except these four—toward the center, away from the center, straight ahead, or straight behind—planets would appear to be coming closer to us or getting farther away from us, and the spectroscope could measure this speed of approach or recession.

So it is with the stars. Those directly ahead of us or behind us in our revolution about a common galactic center, and those toward the center and away from the center, show no motion in the line of sight to be measured by the spectroscope. (This would be true except for the special motions al-

readily mentioned, usually slight, for which correction can be made.) All other stars—all that are not in these four directions—both those farther from the center of the system than we are and those closer to it, have more or less apparent motion in the line of sight. Those having the greatest motion are the stars half way between the points of no motion. Therefore, at 45° along the Milky Way to each side of the center of the stellar system and at 45° each side of the anticenter maximum radial motion is indicated by the spectroscope.

Hence, spectroscopic measurements of radial velocities of stars along the Milky Way will show where the center is, around which the stars revolve. It must be at one of the points of zero radial velocity, and half way between two points of maximum velocity. It is found to be in the Milky Way in the direction of the great star clouds of Sagittarius and Scorpio. The anticenter (180° from the center) is in the Milky Way where the constellations of Taurus, Auriga, and Gemini meet. A third point of interest is the one toward which the solar system is moving. It is in the Milky Way also, and naturally is at right angles to the line leading to the center. It is located in Cygnus, near the star Deneb.

The distance to the center, as well as the direction to it, can be found from the star velocities given by the spectroscope. The principle upon which this is done may be briefly stated. A star at the same distance as the sun from their common center of revolution would, if fairly near the sun, be almost in the tangent to the sun's orbit (that is, 90° from their common center). But if the star is six or eight thousand light years ahead of the sun, it would have turned in toward the center several degrees from the tangent at the sun. At a thousand light years distance it would be seen about 1° off the tangent, or 89° from the center instead of 90°. Cepheid variables were measured out to a distance of about 8,000 light years from the sun. The direction to a star at that distance with no radial motion is not quite the same as the direction to a closer star with no radial motion. There is a measurable angle which gives the curvature of the sun's orbit (see Fig. 3). Joy's result with Cepheids and the results of others using different classes of stars agree very well in giving about 33,000 light years as the distance of the solar system from the galactic center in Sagittarius.

The diameter of the whole stellar system has been estimated at about 100,000 light years; hence our place in the system is about two-thirds of the way out from the center toward the edge of the Milky Way, in the direction of the constellation Auriga and away from the constellation Sagittarius.

Another interesting value growing out of these spectroscopic measurements is the velocity of sun and stars around the great central nucleus of star clouds.

The result actually given by the star's spectrum is the component of velocity directed toward or away from the observer (see Fig. 3). The maximum value of this line-of-sight velocity is called "Oort's constant" because it figures so prominently in the method devised by Oort for studying galactic rotation. It is a constant quantity for any given difference in distance to stars along the Milky Way: for each additional 1,000 light years in any of the four directions of maximum radial motion, the radial motion increases about $3\frac{1}{2}$ miles a second. Thus, for a star at 8,000 light years from us the spectroscope should show a velocity of about 28 miles a second. Using the well-known laws of gravitation, this value can be related to the speed of rotation of the galaxy. Oort worked out an equation in which his "constant" would be one of the known terms, the distance to the center another known term, and the velocity of the sun the unknown term to be found.

Based upon the above principles various observers have arrived at somewhere near 170 miles a second as the velocity of the sun and its planets in their revolution around the center. Most of the stars that are near enough to be visible to the naked eye move at about the same speed, and that is why a great telescope is needed to study the revolution of the galaxy.

Knowing the velocity of the sun and its distance from the center it is a mere matter of arithmetic to find its period of revolution around the center. The radius of the orbit is 33,000 light years, each light year being nearly six trillion miles. The period found

proves to be in the neighborhood of 200 million years.

Geologists place the age of the earth at around 2,000 million years, basing their estimate on the chemical analysis of rocks containing the radioactive element uranium and a peculiar kind of lead into which it very slowly changes at a known rate. The relative amounts of the two metals show when the rock was formed. From these figures it would seem that the sun and earth have had time for only about ten revolutions around the distant center of the stellar system since the earth was formed and solidified.

Slow and difficult as it has been to work out and prove this theory of galactic rotation, the theory simplifies astronomy by relating to one another various puzzling facts about motion that are hard to understand one by one. Such matters as "star streaming," "asymmetry of motion," and "high and low velocity stars," are more easily explained together than separately. In this respect the rotation theory has, in a measure, paralleled the heliocentric theory of the solar system by which Copernicus explained such riddles as "retrograde motion" of planets.

DOMINION

Now Man must take unto himself dominion,
The sovereignty he has given his inventions.
His is the brain behind his own machinery,
Should ever the lesser dispossess the greater?
The use beneficent, not the use injurious,
Should be his program, his unceasing doctrine.
The silver bird that spreads its wings to heaven
Man's glorious conquest of the sky announces,
But how does Man reward his own bright genius?
By hurling down—upon himself!—destruction.
And on he goes, discovering and inventing,
An artless child near gas with matches playing,
The power he takes from earth's entrails will seize him,
With earth-shaking fury rend him, him and his offspring.
Before he further searches out the atom,
Let him ask himself this question: "Am I ready?"
Until he is, he had better stay his power
And look within. And look within. God help him!

—Elizabeth Parkhill Jordan

ARTESIAN WATER AND AUSTRALIA'S PASTORAL INDUSTRY

By JAMES E. COLLIER

AUSTRALIA is one of the leading nations of the world in the development of pastoral industries. It ranks first in number of sheep, with 116 million head in 1940; the U.S.S.R., ranking second, has 110 million; the United States, third in rank, has but 50 million, while Argentina has 44 million and the Union of South Africa 38 million. Australia supplies more than one-third of the world's total wool exports and ranks second to New Zealand in mutton exports. Cattle are second to sheep in Australia, both in number and in derived income. In 1940 the Commonwealth ranked fourth among the cattle-raising nations of the world, with 13 million head; the United States, the U.S.S.R., and Argentina had 72, 53, and 33 million head, respectively, and the Union of South Africa had 12 million.

CHARACTERISTICS OF PASTORAL INDUSTRY

Land Use. In Australia practically all the one billion acres of land leased from the Government and most of the 184 million acres of privately owned land are devoted to pastoral

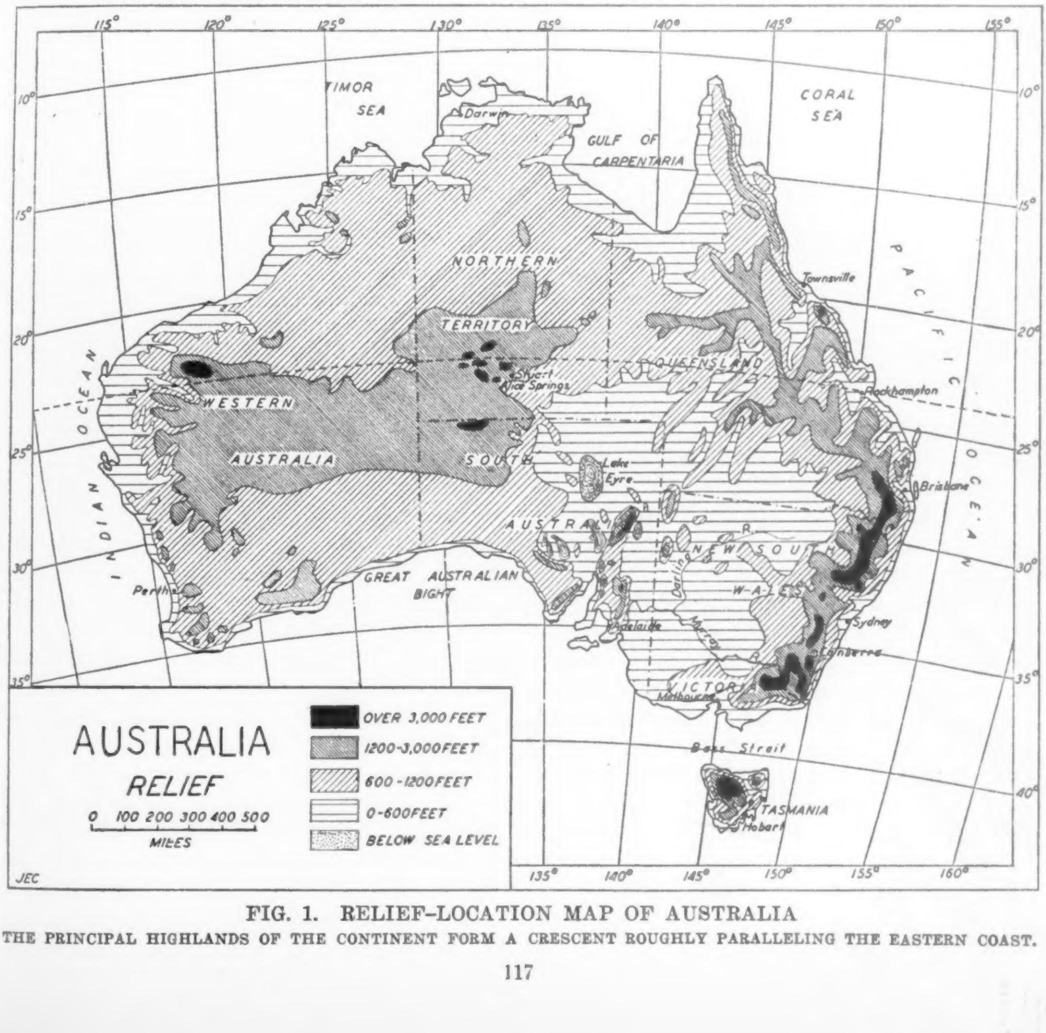

FIG. 1. RELIEF-LOCATION MAP OF AUSTRALIA

THE PRINCIPAL HIGHLANDS OF THE CONTINENT FORM A CRESCENT ROUGHLY PARALLELING THE EASTERN COAST.

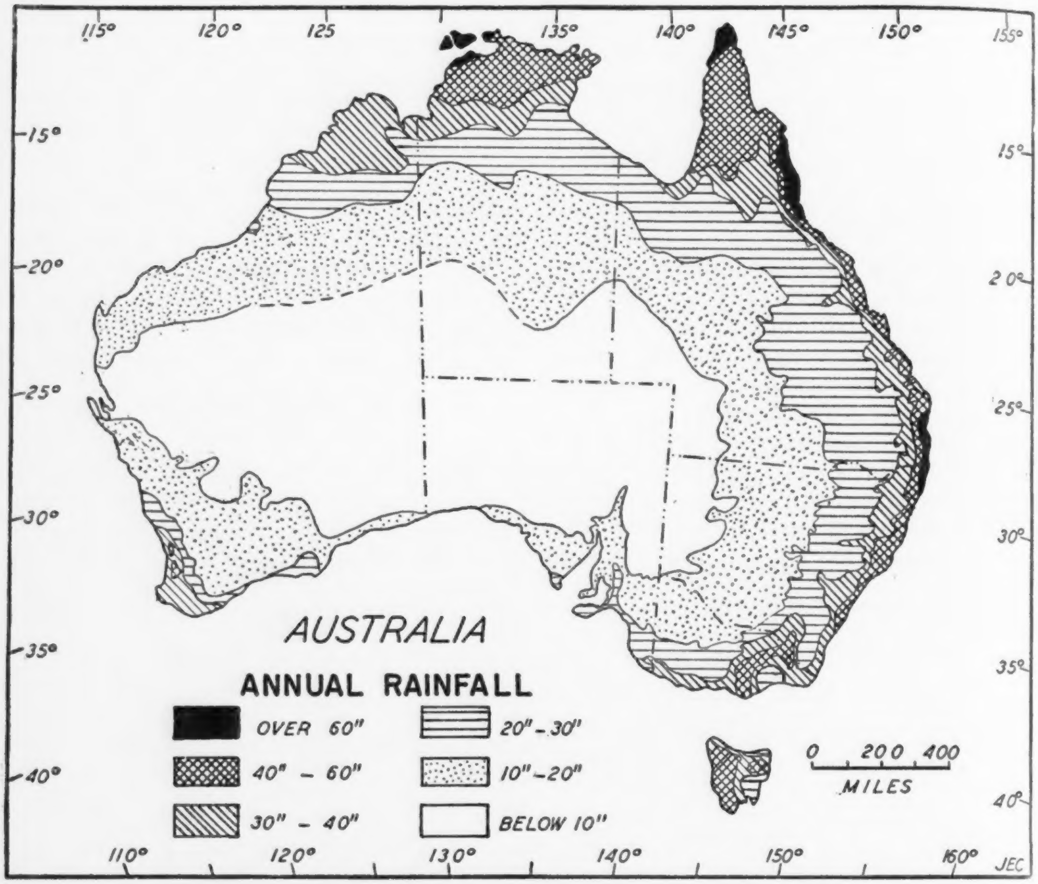

FIG. 2. AVERAGE ANNUAL RAINFALL OF AUSTRALIA

ONLY ONE-SEVENTH OF THE CONTINENT HAS AN ANNUAL RAINFALL OF AS MUCH AS 30 INCHES; TWO-THIRDS HAS LESS THAN 20 INCHES; ONE-THIRD LESS THAN 10 INCHES. DATA TAKEN FROM YEARBOOK OF AUSTRALIA.

use. This is more than half the total acreage of the country. On the greater part of this grazing land the forage is the natural growth of grasses, bush, and shrub. Most of it is found in the eastern half of Australia in the states of New South Wales, Victoria, and Queensland (Fig. 1), but some occurs in the regions to the south, west, and north of the desert core of the continent. Approximately one-half of the area of Western Australia is sparse grazing land best adapted to sheep.

Almost 40 per cent of the area of the Commonwealth is classified as wasteland because of low and uncertain rainfall and the absence of surface or subterranean supplies of water.[1] Practically all of this type of land occurs in the interior of the continent, although it extends almost to the Great Australian Bight on the south.

Rainfall Conditions. The chief reason for the extensive development of the pastoral industry in Australia is obviously lack of adequate rainfall for normal humid agriculture. Only one-seventh of the continent has an annual rainfall of as much as 30 inches (Fig. 2), two-thirds has less than 20 inches, and more than one-third has less than 10 inches. The semiarid land of Australia is four times as extensive as that of the United States. One-third of the continent is permanently drought-stricken, and one-half has no rains for six months or more of the year. Moreover, because of the relatively high temperatures—two-fifths of Australia lies in the Tropics—the rainfall received is not so effective as similar amounts in cooler latitudes. The annual evaporation ranges from 31 inches in the cool, humid southeastern re-

gions to more than 100 inches in the arid interior. In the desert area of Western Australia the rainfall is 9 inches and evaporation is 145 inches a year.

In addition to being very limited in amount, the rainfall of the Australian interior is erratic and unreliable, being derived largely from thunderstorms. Most of it comes during the warmer season, but at best the grasses dry up for much of the critical summer period. At Stuart (Alice Springs) in the Northern Territory there is an annual average of 10.79 inches, but in 1918 only 4.2 inches fell and two years later 28.57 inches. The average annual evaporation at the Stuart station is 96 inches. Roebourne, on the northwestern coast of Western Australia, has an average annual precipitation of 15 inches, but in 1891 there was less than 1 inch and in 1900 as much as 42 inches.

Pasture, Range Capacity, and Holdings. The most valuable pasture lands are those of the regions of temperate grassland, temperate forest, tropical grassland (chiefly Mitchell grass), savanna grassland, savanna woodland, and saltbush (Fig. 3), approximately in the order listed. Most of the areas of temperate forests and some of the savanna woodland and temperate grassland are suitable for cultivated crops and are not altogether pastoral in use. There is some grazing even in these more humid areas. In the regions of tropical grassland, savanna grass-

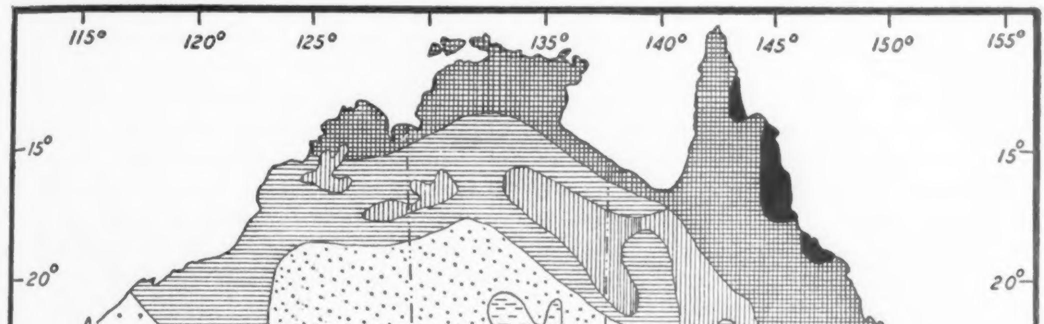

FIG. 3. NATURAL VEGETATION OF AUSTRALIA

DISTRIBUTION OF THE TEN TYPES: 1, TROPICAL RAIN-FOREST; 2, SAVANNA WOODLAND; 3, SAVANNA GRASSLAND; 4, TROPICAL GRASSLAND; 5, SALTBUSH; 6, SCRUB WOODLAND (MALLEE); 7, ARID MULGA; 8, FIXED DUNES; 9, TEMPERATE GRASSLAND; 10, TEMPERATE FOREST. AFTER GRIFFITH TAYLOR AND MACDONALD HOLMES.

land, arid mulga (acacia), and saltbush, development is almost entirely pastoral.

The grasses of the northern savannas dry up for about six months of the year, and the stock subsists on the resulting natural hay. This forage is more nutritious in the areas with less than 20 inches of rainfall. With more than that amount the grass ripens before the end of the rainy season and is leached of much of its nutritive content by the continuing rain. Common practice is to burn this grass as soon as it becomes dry and to graze the cattle on the new short grass that grows before the soil moisture is lost. This does not suffice until the next rains, however, and the herds become underfed and lose considerable weight before the beginning of the rainy season in December.[2] The greatest pastoral activity of northern Australia, therefore, is between the 15- and 20-inch isohyets, where the grass, when dry, achieves its maximum nutritive value and where there is not too little rain for an abundant growth of these grasses. Some grasses are better than others. Mitchell grass is perhaps the best, and its success is due to its heavy carrying capacity, together with a tendency to improve rather than deteriorate under relatively heavy grazing.

In the better parts of the sheep-grazing region, with 20 inches or more of rainfall, the density of the sheep population is about one for each three acres of grazing land. In the arid grazing lands of the southern part of Northern Territory there are 130,000 head of cattle and 5,000 or 6,000 sheep. If we consider nine sheep the equivalent of one cow in grazing requirements, the grazing area per animal unit in a territory of approximately 700,000 square miles is about 640 acres. In the comparable arid grazing region of western United States only 75 acres are required.

The area necessary to yield an adequate income to each population unit (a family of four) varies from 10 to 50 acres on the humid east coast. In the wool and wheat zone of the western slopes of the major highland region an area of 300 to 600 acres is necessary. In the drier regions of the interior the acreage requirement increases to tens or hundreds of thousands of acres. The type of operation is in direct response to these conditions. Companies with large assets can persist better than individuals. Over wide areas a good rainfall season in one part tends to balance the poor season of another. Rarely do droughts affect all portions during the same year. Large holdings are essential if stock is to be moved from regions of drought to areas in which the rainfall has been more nearly normal.

In all the agricultural and pastoral regions of the Commonwealth in 1938 there were 233,125 private holdings, including both owned and leased land, embracing an area of 180,597,000 acres, an average of 775 acres for each holding.[1] The leased land in 1939 totaled 887 million acres in 254,294 holdings, an average of 3,488 acres per holding. These range from 100 acres to a half-million acres in extent. Two-thirds of the number of holdings comprise 12 per cent of the land area, while 19 per cent includes approximately three-fourths of all the privately held land (owned and leased). In this latter category are found the huge cattle and sheep stations of the arid and semiarid interior. In western New South Wales, for example, 85 per cent of the holdings range from 20,000 to 100,000 acres in size, and some contain as many as 400,000 acres.[3] In this same area there is one sheep to each 20 acres of grazing land. The average number of sheep for each individual holding is 1,146. Stations with 5,000 or more sheep dominate the industry. More than one-half of the 50 million sheep are on one-tenth of the holdings, all of which are of enormous size.

Water Supply for Stock. Extensive grazing in regions of less than 20 inches of rainfall is possible only with a supplementary supply of water for the stock. It is lack of such water rather than shortage of forage that puts a limit on pastoral occupance in much of the Australian interior. The rainfall-evaporation ratio of regions with low annual rainfall prevents the accumulation of surface water except in the case of occasional water holes and the lakes of the interior, most of which are saline. Except for the Murray–Darling system in the southeast, no large permanent streams flow from the humid regions through the drier areas. The Murray and Darling Rivers furnish water for some irrigation, but little is used for stock.

Along the intermittent streams of interior Australia there are occasionally long, ribbon-like water holes that have been scoured deeper than the remainder of the channels and that retain water for varying lengths of time after the infrequent thundershowers and floods. Descriptions of these water holes as they occur in western Queensland indicate that they are becoming less and less dependable as sources of surface water supply, because major floods to replenish them are becoming more infrequent.[4]

The hazardous character of pastoral development is minimized by damming the rivers in the eastern mountain zones in order to furnish permanent stock water areas, by preservation of special grazing areas in submarginal agricultural lands, and by the use of artesian water. The permanent mountain and highland streams that may be dammed to create reservoirs supplementing other supplies of water are very limited in their scope. Over a much larger area it is possible to tap the waters of the several artesian basins, and on the whole this source of water plays a much more important part in the grazing industry than any other. It is this source that is under consideration at the moment.

The irregularity of rainfall from year to year as well as the small annual totals makes the supply of stock water of extreme importance during some years. The vegetation usually persists and in most years provides sufficient forage, but a supplemental water supply is necessary for the sheep and cattle. This is obtained for the most part from artesian wells.

In addition to meeting a vital need of water supply during normal years, artesian water along the routes of movement makes

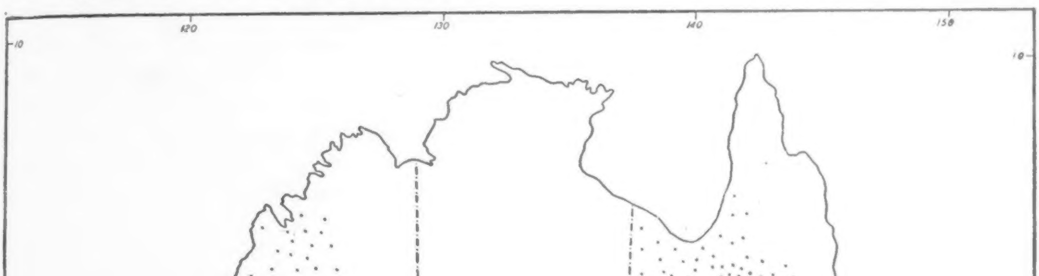

FIG. 4. DISTRIBUTION OF SHEEP IN AUSTRALIA

DATA FOR THIS MAP AND FOR FIG. 5 TAKEN FROM YEARBOOKS OF THE STATES AND FROM THE REPORT ON THE ADMINISTRATION OF THE NORTHERN TERRITORY BY THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

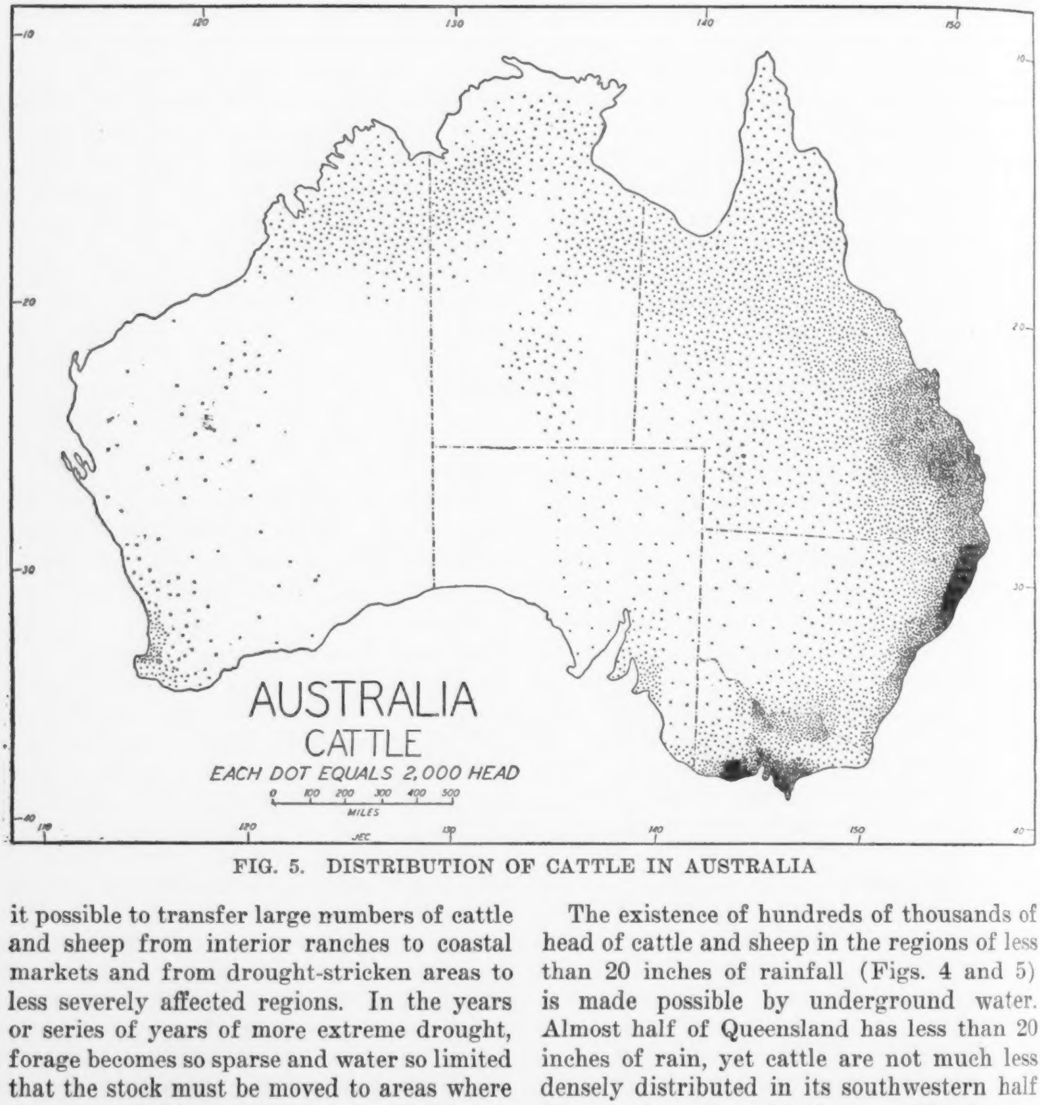

FIG. 5. DISTRIBUTION OF CATTLE IN AUSTRALIA

it possible to transfer large numbers of cattle and sheep from interior ranches to coastal markets and from drought-stricken areas to less severely affected regions. In the years or series of years of more extreme drought, forage becomes so sparse and water so limited that the stock must be moved to areas where drought conditions are less severe if the animals are to survive. In recent years artesian wells have been drilled, and tanks and reservoirs constructed along the routes of migration, making a supply of water available for the movement from stricken areas and thus reducing the severe losses that have been sustained in the past. Routes from many of the isolated grazing areas of the interior to markets or railheads are served in the same manner. The transference of large herds of cattle for hundreds of miles over the stock routes, which are the roads of much of inland Australia, is a routine part of the life of the cattlemen.

The existence of hundreds of thousands of head of cattle and sheep in the regions of less than 20 inches of rainfall (Figs. 4 and 5) is made possible by underground water. Almost half of Queensland has less than 20 inches of rain, yet cattle are not much less densely distributed in its southwestern half than in the eastern highlands, which have a considerably greater rainfall. Most of the cattle of Northern Territory exist by virtue of the artesian water. In the coastal zone of the Territory, with 30 to 50 inches of rain, temperatures are generally too high for successful cattle raising; whereas in the central and southern portions, where temperatures are more favorable, the rainfall is low and additional water is required. There are 14 million sheep, 12 per cent of the country's total, in central Australia where the rainfall is inadequate and where ground water must supplement it. Most of the cattle and sheep of Western Australia are found in areas in

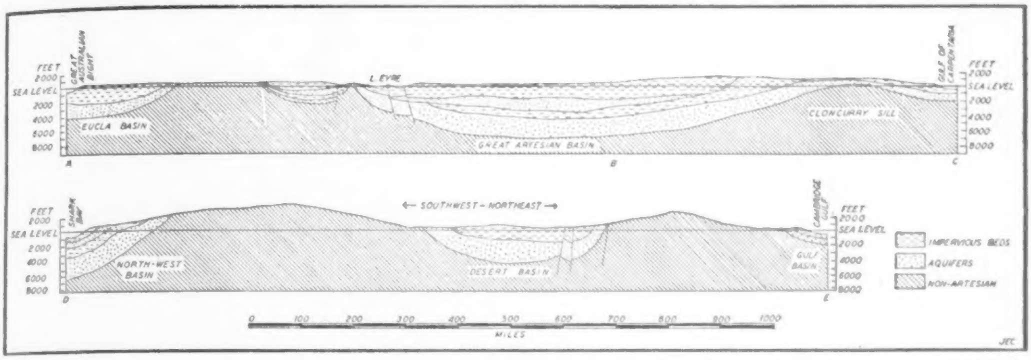

FIG. 6. CROSS SECTIONS OF ARTESIAN BASINS
TAKEN ALONG LINES ABC AND DE OF FIG. 7. ADAPTED FROM T. W. E. DAVID, GEOLOGICAL MAP OF AUSTRALIA.

which artesian water is available. Except in the northeast and southwestern portions the rainfall of Western Australia is 20 inches or less.

On the lower western slopes of the eastern highlands of Australia cattle and sheep replace the wheat and other crops of the more humid upper and eastern slopes. The artesian water of the Murray River Basin is of significance, making possible the development of grazing there. Northwestern Victoria has its semiarid region, a continuation of that of New South Wales, although less extensive. In South Australia there has also been extensive development of grazing. The Murray River and smaller artesian basins underlie the southern and eastern portions of this state, and the Great Artesian Basin extends from Queensland into the northeastern part of the state.

A specific example may be cited to illustrate the value of artesian water and the part it plays in stock raising.[5] A sheep station in New South Wales contains 520,000 acres of land and grazes a maximum of 120,000 sheep. Large areas of the holding consist of extensive plains on which the natural vegetation is saltbush, cottonbush, native grasses, and other herbaceous plants. The rainfall of the area is 15 inches, and temperatures range from 118° F. on hot summer days to 30° or 40° on some winter nights. From October to March the grasses become dry, and the plains are devoid of green feed during the hottest months of the year. The sheep have been bred to withstand without protection the arid heat of summer and the comparative cold of the winter months that follow. A system of tanks and artesian wells, together with water from occasional intermittent creeks, supplements the inadequate and unreliable rainfall. Without the artesian supply, watering facilities during the dry summer months would be inadequate, and the carrying capacity of the range would be limited to the rather small number of sheep which could survive on the water that could be held over in tanks and reservoirs and on the yield of the intermittent streams.

Artesian Basins

The large area of Australia in which artesian water is found has no known counterpart. The largest of the basins is the largest known artesian basin in the world. In almost one-third of the Commonwealth artesian or subartesian water may be obtained at depths of 10 to 6,000 feet. The basins are old arms of the sea into which were deposited porous sands, which were in turn covered with fine clays and silts. Today thirteen distinct basins, ranging in size from a few score square miles to more than 600,000 square miles, make possible the human occupance of vast areas of arid and semiarid land.

Development. The first artesian well of Australia was put down near Bourke, New South Wales, in 1879. The Government sank a successful well in the same vicinity in 1884. The first well in Queensland was drilled at Blackall in the south-central part of the state in 1885. Within two years of that date a number of wells had been drilled in the area. By 1909 there were over 2,000 active wells in Australia (Table I).

TABLE I

ARTESIAN AND SUBARTESIAN WELLS IN AUSTRALIA

IN 1909

Characteristics	New South Wales	Victoria	Queensland	South Australia	Western Australia	Northern Territory	Australia
Number of wells	480	25	1,580	33	80	e	2,198b
Total depth (ft.)	763,879	5,937	1,644,400	50,377d	88,266	e	2,552,859b
Daily flow (1,000 gal.)	116,000b	e	520,300	10,947	26,505	e	673,752b
Depth at which artesian water was reached (ft.):							
Maximum	4,341	466	5,045	4,850	3,011a	e	5,045
Minimum	46	140	60	233	420a	e	46
Temperature of water (°F):							
Maximum	140	e	202	208	140a	e	208
Minimum	70	e	60	78	60a	e	60
IN 1939							
Number of wells	737	620	6,774	162a	281	191	8,765b
Total depth (ft.)	1,132,322	30,000	4,839,000	115,598	229,391	63,375	6,409,686b
Daily flow (1,000 gal.)	67,349	2,500	250,000	12,972	75,351c	7,723	340,544b
Depth at which artesian water was reached (ft.):							
Maximum	4,380	3,560	6,000	4,851	4,006	1,760	6,000
Minimum	100	20	10	233	30	42	10
Temperature of water (°F):							
Maximum	140	120	212	208	e	e	212
Minimum	75	60	78	82	e	e	60

a Government wells only. b Incomplete record. c 1933. d Flowing wells only. e Data not available.
(From Year Book of the Commonwealth of Australia, 1911, 1940.)

Most of these wells were in the three eastern states. Queensland alone had 1,580, and the three together had 2,085 wells. In Western Australia and South Australia there were but a few more than 100 wells at this time.

In 1939 there were 6,774 artesian and subartesian wells in Queensland, 737 in New South Wales, 620 in Victoria, more than 160 in South Australia, 191 in Northern Territory, and 281 in Western Australia, a total of nearly 9,000 or possibly more, since this figure is incomplete (Table I).

Great Artesian Basin. The largest of the basins is the Great Artesian Basin of Queensland, Northern Territory, northern New South Wales, and northeastern South Australia (Fig. 7). It extends under about one-fifth of the continent. In an area reaching for 1,270 miles in a north-south direction and for 900 miles east and west, individual wells yield from 100,000 to more than 2,000,000 gallons of water daily. The yield from flowing wells alone is 450 million gallons a day, and many wells do not overflow. In Queensland about one-third of the wells are flowing, two-thirds must be pumped, and one-fourth have failed. In New South Wales about two-thirds of the number of wells are flowing and one-third are subartesian.

The underground water of the Great Artesian Basin is derived principally from rainfall on the underlying porous sandstones and massive limestone beds of the basin where they reach the surface on the western flanks of the Great Australian Highland, marking the eastern extent of the basin. The average

annual rainfall on these intake beds is 20 to 30 inches. The aquifers also reach the surface on the western side of the basin in western Queensland and in Northern Territory. The rainfall in these areas is less than 20 inches, and probably a relatively small part of the underground supply is derived from this source. This surmise is strengthened by the fact that over most of the basin the water moves southwestward toward the region about Lake Eyre. Some reinforcement of waters is received from the Camooweal Basin, which joins the Great Artesian Basin on the northwest. In northern Queensland the water works its way northward over the Cloncurry Sill (Fig. 6), a rise in the underlying complex of older rocks on which the deepest aquifer rests, and finds an outlet under the waters of the Gulf of Carpentaria. The intake beds are exposed on the surface over an area of 60,000 square miles, one-tenth as great as the area of the basin itself.

Groups of mound springs in various parts of the basin mark areas in which the water-bearing strata reach or closely approach the surface, or where faults provide avenues of upward passage through which the water works its way to the surface. Lake Eyre is, in effect, the exposed surface of the water table. The excessive evaporation in that region prevents the lake from becoming larger. The springs build circular mounds of sand and silt, which may become cemented to form basins in which the water collects to form pools. The mounds may be 15 to 20 or even 30 feet in height and 100 feet or more in diameter. Each mound spring usually contains a crater in which there is water if the walls of the mound are not too porous.

The structure of the Great Artesian Basin and of practically all the others is that of inclined porous strata, mainly sandstones, overlain by impermeable clays and shales. Many of the basins are gently dipping, shallow synclines. Although the pressure seems to be essentially hydraulic, obtained through resistance to flow, in part it may be due to gas pressure and to vertical rock pressure.[6]

The temperature at which the water reaches the surface varies from 60° to 212° F. The thermal gradient is so high that the water from some of the wells reaching the deepest part of the basin is boiling. In many of the wells it reaches 140° F. The gradient increases westward. In the east it is approximately 1° F. for each 40 or 50 feet in depth, in the central part of the basin 1° for each 30 feet, and in the southwest in the vicinity of Lake Eyre 1° for each 20 feet. The average gradient is about 1° for each 37 feet in depth below the zone of mean surface temperature.[6]

Most of the artesian water is good, but in some instances the high salinity decreases its value. Relatively few wells are entirely unusable because of mineral content. Even if unsuitable for domestic purposes, the water may not be too saline for use as stock water, which is perhaps more critical because of the greater quantities required. The most common mineral salt in the water is sodium carbonate. Occurring in smaller quantities are sodium chloride, potassium carbonate, silica, and calcium carbonate, in decreasing order of abundance. Subartesian water is more apt to be brackish than is water derived from flowing wells, since the former is in contact for a longer period of time with the shallower strata and sometimes is stagnant.

The salinity of the waters of the Great Artesian Basin increases southwestward with distance from the intake beds. In the east there is generally less than 10 grains of sodium carbonate per gallon of water, with smaller quantities of other salts. In the vicinity of Lake Eyre the content may rise to 20 grains or even more. An analysis of the waters of a well at Bourke, New South Wales, in the southern edge of the basin, indicates a content of 33 grains of sodium carbonate and 12 grains of other solids.[7] The salts are presumably derived from saline marine beds with which the percolating water comes in contact.

Lake Eyre, the natural outlet of the basin, is in reality a large area of salt marsh and crusted flats, all below sea level. Not all the salt is derived from evaporated groundwater, since the lake is a remnant of an arm of the sea that was cut off by the sediments deposited in a Cretaceous sea which extended from the Gulf of Carpentaria almost to the Great Australian Bight. Except for the high rate of evaporation, a huge inland sea would probably exist today at the site of the lake.

The marginal, high-level basins shown on

the map (Fig. 7) may be continuous with some upper or suspended aquifers of the Great Artesian and Murray River Basins. To what extent they overlap with the main basins is not known, except that the records of existing wells indicate the presence of aquifers above the major water-bearing strata of the larger basins. In all essential respects the marginal basins are similar to the larger ones, differing only in size and in the depth at which water is tapped.

That percolated rainfall is the chief source of the supply of water is indicated by the even hydraulic grades, by the seasonal variations in some of the basins, by the relative freshness of water from some deeper strata as compared with the mineralization of stagnant water in some of the suspended aquifers, and by the large volume of atmospheric nitrogen, with some argon, discharged by the wells.[6]

Desert Basin. The second largest of the artesian basins is the Desert Basin of the northern part of Western Australia. It has an area of approximately 130,000 square miles in which artesian and subartesian water is found. The deepest well from which artesian water is obtained is 4,000 feet, and the average depth of flowing wells is approximately 700 feet. Individual wells yield 7,000 to 1,000,000 gallons of water daily.

This basin is of the usual three-sided type, opening seaward (Figs. 6, 7). The aquifers rise to the surface in the northeast and dip gently to the southwest and west. The waters find an outlet in the Indian Ocean between King Sound at the mouth of the Fitzroy River and Ninety Mile Beach. The rainfall on the porous sandstones that carry the water underground is limited to 21 inches or less, and not much water could be added to the basin on its eastern and southern margins, since the rainfall in these areas is only 10 inches. The bulk of the water supply is probably derived from the intake areas along the val-

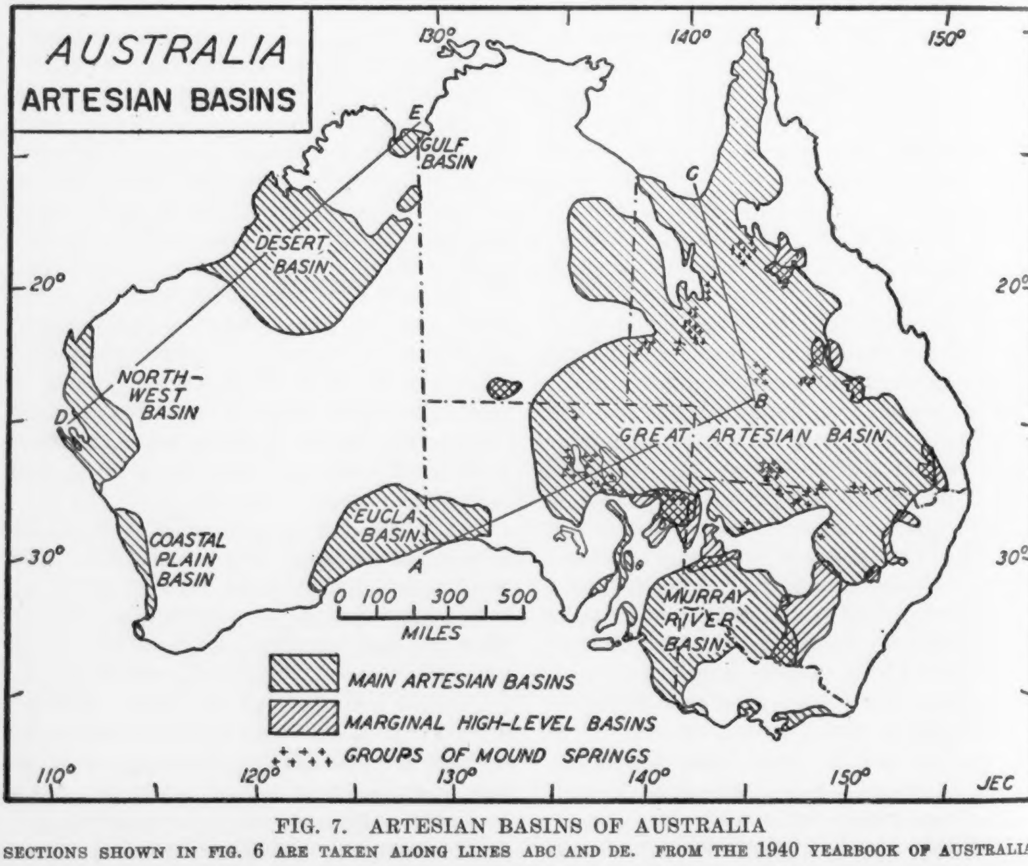

FIG. 7. ARTESIAN BASINS OF AUSTRALIA

SECTIONS SHOWN IN FIG. 6 ARE TAKEN ALONG LINES ABC AND DE. FROM THE 1940 YEARBOOK OF AUSTRALIA.

ley of the Fitzroy River on the northeast. The beds are breached in several places by small streams, much of whose water disappears underground. The savanna and savanna grassland of the area make good cattle country. In the eastern, desert portions of the basin even cattle are few in number, and the area is entirely unsuited to sheep.

Murray River Basin. The Murray River Basin of southwestern New South Wales, western and northern Victoria, and southeastern South Australia is approximately 90,000 square miles in extent. An artesian flow of 210,000 gallons daily is obtained in the western part of the basin. Much of the water is subartesian, however, and hydraulic pressure is not sufficient to force it all the way to the surface. The intake beds are on the southern and eastern edges of the basin, where the rainfall reaches 30 or 40 inches. The volcanic lakes of Mount Gambier in the extreme southeastern portion of South Australia represent the exposed hydraulic surface. Their level is directly dependent on the rainfall on the intake beds in Victoria, about 80 miles to the northeast. The water supplies of this basin are particularly valuable in the mallee country of northeastern Victoria.

Camooweal Basin. The Camooweal Basin is geologically an arm of the Great Artesian Basin in western Queensland and extends into the Northern Territory. The limestone aquifers dip southeastward into Queensland. On the northeastern edge of the basin they come to the surface and create the most powerful springs in Australia. These springs form the sources of the Gregory and O'Shanassay Rivers, which discharge northward into the Gulf of Carpentaria. The springs at the head of Gregory River are estimated to have a flow of 83 million gallons of water a day, and those of the O'Shanassy 23 million gallons. Much of the ground water of the Camooweal Basin continues southeastward to reach the aquifers of the Great Artesian Basin in western Queensland or comes to the surface to form the mound springs of west-central Queensland.

Eucla Basin. The Eucla Basin, bordering on the Great Australian Bight in southwestern South Australia and adjacent parts of Western Australia, has an area of 52,000 square miles. The water is mostly subartesian and is obtained at depths ranging from 300 feet to more than 2,000 feet. The water rises in the subartesian wells to a height equal to sea level. Only one well has been proved artesian, but only 20 or so have been drilled, most of them along the transcontinental railroad, which traverses the basin in an east-west direction. The artesian well yields 5,700 gallons of water a day but does not pierce the full thickness of the water-bearing strata. The region of the basin is known as the Nullarbor Plain and is an area of karst topography developed on a white cavernous limestone underlain by sandstones, shales, and conglomerates, which rest in turn on a crystalline floor. The basal beds dip gently southward to the Great Australian Bight into which the percolating water finds an outlet.

Some of the water of the Eucla Basin is too saline for livestock, containing as much as three ounces of salt per gallon, but much of it is usable. The water from the wells on the western side of the basin is fresher than that from the eastern portion. The pastoral industry of the region is not well developed, chiefly because of this salinity of the water and the difficulty of obtaining permanent water storage on the permeable limestone. The vegetation is mainly saltbush, with a margin of scrub woodland along the coast.

Northwest Basin. The Northwest Basin has an area of 40,000 square miles and provides water at depths of 400 to 4,000 feet. Most of the water is under sufficient pressure to bring it to the surface, but it must be pumped from some of the wells. The permeability of the sandstone beds, which make a bold outcrop in the Kennedy Range to the north, is well adapted to the absorption and transmission of large quantities of water, while their thickness gives them a large storage capacity. The saline nature of some of the higher-level beds makes the water from them somewhat less pure and useful than that from deeper wells. The greatest daily flow from a single well is 2,600,000 gallons. The strata of the basin have a regional dip

westward. They outcrop in the highlands to the east of the basin and absorb water from streams flowing across them as well as from the rainfall on the intake beds. The area is not well developed. Only 66 wells have been drilled. The presence of the artesian water may make further pastoral development possible.

Coastal Plain Basin. The Coastal Plain Basin is one of the smaller of the artesian basins, being only 10,000 square miles in extent. Water is obtained at depths of 200 to 2,500 feet. The estimated percolation of rain and river water is 22,000,000 gallons a day. The daily flow from artesian wells in the basin is about 16 million gallons, and about 2 million gallons are pumped from subartesian wells. Thus there is an approximate balance between intake and withdrawal. Records of the pressure in wells about Perth indicate that they return to their original pressure four to six months after the heavy withdrawal during the summer has ceased. A known deeper aquifer, likely to contain large volumes of good water, has not yet been tested or developed.

The mean annual rainfall on the outcropping aquifers along the eastern side of the basin is 20 to 30 inches. Considerable ground water is derived also from the streams flowing across the exposed porous beds. From the data of gauging stations it appears that several hundred thousand gallons of water disappear underground daily in the valley of the Helena River and other streams that cross these strata.

Other, Smaller Basins. Six additional, smaller artesian basins, ranging in area from 300 to 4,000 square miles, are found in various parts of Australia. At the mouth of the Ord River in northeastern Western Australia is the Gulf Basin. The rainfall is approximately 30 inches on the northwestward dipping limestone and sandstone strata. Several deep wells have been drilled, but no overflowing wells have yet been developed. The small Pirie–Torrens Basin, extending northward from Spencer Gulf into South Australia, has an area of 4,000 square miles. Its water is both artesian and subartesian and may be obtained at depths of less than 600 feet. Some of the water is saline, but most of it is suitable for livestock. The Adelaide Plains Basin, extending from Adelaide northwestward to the head of the Gulf of St. Vincent, is one of the smallest of the basins, containing only 600 square miles. Its water is for the most part of good quality. Most of it is subartesian and is tapped at depths of less than 500 feet. The Port Phillip and Gippsland Basins on the coast of Victoria yield subartesian water and are relatively shallow. In the former the deeper water is brackish, but much of the more shallow is good. The best well of the Gippsland Basin yields 500,000 gallons daily.

Decline of Water Supply. The rate of withdrawal of water from the artesian basins of Australia is greater than the rate of replenishment from rainfall on the absorbing beds, and the level of the water is gradually declining. The average rate of decline is given as approximately 3 per cent annually, but it is greater in the eastern basins, which were developed earlier and more fully than were those of central and western Australia. A number of wells that were originally artesian are now subartesian, the dissipation of hydraulic pressure being sufficient to cause the wells to cease to flow. The volume of flow from practically all artesian wells has declined in recent years. The total daily flow in 1909 was more than 563 million gallons, but in 1939 it was approximately 340 million gallons (Table I). In the same period the number of wells increased fourfold.

Two factors are responsible for the decline of water supply: (1) The rate of withdrawal of underground water in recent decades has been greater than the rate of absorption, a fact that can be seen in the decreased flow of individual wells and springs and in the lower level of subartesian waters. (2) There has also been a general decrease in the rate of absorption of water by the aquifers of the Great Artesian Basin in western Queensland, and probably elsewhere also, because of a general decline in the rainfall during the past twenty years and probably since Pleistocene time.[4, 8] This decrease in absorption of ground water is due not only to a decrease in rainfall but also to consequent decline of vegetation, greater runoff, and increased soil

erosion. These natural decreases have been amplified by human agencies.

The decrease in flow of water from some artesian wells may be the result of corroded or ill-fitting casings, permitting escape of the water into the porous strata above the level of the water-bearing beds. Partial obstruction of the bore by sand, silt, or some mineral product may decrease the flow. Only overdraft is cause for permanent decrease and is irremediable.

A considerable part of the water withdrawn from the underground reservoirs is wasted. The water is often led from the well casing into open drains, which run for miles through the pastures. Evaporation into the dry atmosphere and absorption by the thirsty soil lead to excessive loss through this practice. Estimates have placed the actual amount used for stock water at as low as 3 per cent of the total daily flow.[9]

Future. The developed artesian areas are less extensive than the known basins, and some further development may be possible. If such occurs, it will probably be in the central and western basins. In view of the decline of supply it is probable that the possible extension is very limited and will require more stringent conservation of the supply in areas already depending on the water. Even if no additional wells are drilled, there is a serious need for the prevention of waste and in other ways reducing the drain on the underground reservoirs. The present rate of withdrawal is greater than the rate of replenishment in the intake areas, and the decrease in flow and the lowering of the water level in subartesian wells point to a shrinkage of the areal extent of the basins and added expense of pumping as well as a decrease in the available water supply. This probably is not yet true of the basins that have not been fully developed and in which there has been no decline in the supply of water.

The pioneering stage of development has usually been considered only a temporary one, to be succeeded by a stabilized agriculture and relatively intensive occupancy. The pioneer aspect is less often considered a necessarily permanent condition. It must be permanent, however, in a region that is suitable only for occupancy of a specialized type and that will support only a sparse population. A suitable income may be derived from a specialized product, but if the region is not capable of producing most of the requirements for human occupancy, and if industrial development is impractical as it apparently is in the interior of Australia, the pioneer stage of development can but continue permanently. The inland cattle and sheep regions of Australia are of this type, as is also much of the land within and on the inner margin of the eastern highlands. The limited agricultural resources of three-fourths of the Commonwealth preclude any hope for development beyond pastoral stage. Permanency of even this type of occupancy is possible in most of the regions only by virtue of underground supplies of water, which are derived originally from more humid areas and which are tapped by artesian wells. Even this mode of occupancy is endangered by the lack of proper conservation measures.

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THE SCIENTISTS' POSTWAR PROBLEMS

By HARRY GRUNDFEST

To scientists, as to all other groups of our population, the war has presented many sharp challenges. The structure of American science and the nature of its scientific research have been profoundly modified by the demands of the war effort. Although the war is far from over, scientists are now faced with the need to take stock of their present situation and to set the course of science toward the postwar world.

The problems of scientists in the postwar world will, of course, be conditioned by the nature of that world. In the Teheran Declaration an over-all picture of the world that will follow the victory over fascism has been given us by the responsible leaders of the great powers among the United Nations. The general implementation of this Declaration is now beginning to take shape in our country. Fundamental is an economy of peace that will be at least as productive of its appropriate goods as our war economy has been. Within our country it will mean an economy of plenty based upon standards of living and productivity higher than any ever seen before. This will in turn involve a great expansion of our international markets, but, in keeping with the Teheran Declaration, the expansion will be an aid to, rather than in conflict with, the interests of the rest of the world. It will entail far-reaching changes in our relations with other nations, both with the industrially developed and powerful and with the weaker, less-developed, or colonial countries.

The steps that will be required to carry out the many implications of the Teheran Declaration will also involve changes in the relationship between the people of our country and our Government. Government, as the collective power of the people, will increasingly become an instrument to carry out the policies embodied in the Declaration. I believe that government and the people, as a result of the important contributions which science has made to the war, have learned at long last that the continued development and support of scientific research in the peace will be fundamental in establishing and maintaining a high standard of living and well-being for our country and for the world. And science, which in the past has been chiefly supported by private funds of the universities, foundations, and private industry, will more and more come to look to government to provide the means for a greatly expanded program of work. Through this collaboration the achievements of science will become more immediately available to the needs of mankind. Because of its increased opportunities and responsibilities science will be more responsive to the needs of the nation and better integrated into the general social and economic structure. It should therefore occasion no surprise to find that many of the problems I shall here outline will find their solution in governmental action.

In the following I shall discuss the problems of scientists common to those of other professional and white collar workers, as they were treated at the second National Wartime Conference (June 2 and 3, 1944). At this conference delegates from important scientific societies met with representatives of artists, social workers, librarians, teachers, white collar unions, and other organizations to discuss their common problems in four categories: full employment; readjustment and retraining of the professions; standards of living; and international collaboration in the postwar world.

Full Employment

In the first years of the war many scientists, including the present writer, criticized the tempo and direction of our national mobilization of scientific personnel. This is all now a matter of history. At the present time there is a shortage of scientists in practically all fields. Vast research programs have been developed in the governmental departments, in special centers under control of the Office of Scientific Research and Development (OSRD), by the universities, and by industrial laboratories.

Huge research centers have grown up in the civilian Government departments and in the armed forces, either as expansions of

prewar organizations or *de novo*. Some of these are the National Institute of Health, the Naval Medical Research Institute, the various laboratories of the National Advisory Committee for Aeronautics (NACA) and of the Departments of Agriculture and the Interior, and the specialized laboratories of the armed forces—such as those of the Signal Corps, Air Force, Armored Force, Chemical Warfare Service, and Quartermaster Corps. Large centers established under OSRD have generally been in connection with the universities. As examples may be mentioned the Radiation Laboratories at the Massachusetts Institute of Technology, the Radio Research Laboratory at Harvard University, and special projects at Columbia University, The University of Chicago and elsewhere. Individual departments of various schools have also received grants to investigate war problems. The great prewar laboratories of the industrial giants, such as Bell Telephone, General Electric, General Motors, and du Pont have expanded and are working full blast. Many new firms have come into such fields of war production as the electronics, communications, aviation, metals, and optics industries. They have set up research laboratories to control and improve their products and to establish for themselves a basis for postwar business. Biological, chemical, and medical research has expanded among the firms making pharmaceutical products: penicillin, vitamins, and the like. A new demand for scientific workers has come also from the control laboratories of the many war factories set up throughout the country with Federal funds.

Educational institutions and retired lists have been combed and all available graduates and students have been snapped up to provide the manpower required in this vast program. Schools and colleges have at the same time been forced to curtail their teaching programs, thus making some members of their staffs available for war jobs. Many scientists have resigned from relatively established and stable positions and have migrated to wartime jobs in new communities. Most of them have received salary increases on entering war work, but these increases, generally ranging from about 30 to 50 per cent, have been based on low, prewar levels and have usually not been sufficient to meet the extra costs of new establishments and the higher costs of living, to say nothing of saving for the future.

This is the background against which we must view the problem of postwar employment of scientists. At first their situation appears no different from that of other war workers. Scientists, however, represent the most highly trained group of workers in our society. On their long and rigorous training was spent a considerable amount of the nation's wealth. In keeping with their high degree of training, scientists of necessity are highly specialized. A scientist or engineer working in a technical field only a little removed from his own specialty requires a period of retraining before he can function at maximum efficiency as a skilled technician and creative worker. If he works entirely outside the field of science, he represents nearly a total loss to society so far as its investment in his training and in his potential contributions to the social welfare is concerned. Furthermore, prior to the war there was a scarcity of jobs in the scientific fields. Without the equipment and libraries that laboratories afford him, a scientist cannot practice his highly specialized profession. Because he can work best only in a narrow, but socially extremely valuable, field, he represents a special problem as a war worker.

The future of scientists in the immediate postwar period can be of two kinds. Either science is organized to become part of the expanding international economy developing out of the Teheran agreement, in which it can play a very important part, or it can be allowed to slip back into its prewar pattern. The future under the latter alternative may be rather grim. War research will have stopped; the great wartime research centers may be closed. Cutbacks in industry will be accompanied by curtailment of research. The universities will be in a period of transition and certainly unable to absorb all the unemployed scientists. Consequent upon unemployment scientists would be cut off from their normal sources of contact with their fields and from such knowledge of current developments as is made available through scientific meetings and library facilities. They would face the rapid loss of expert

skills painstakingly acquired. They would be exposed to many psychological disturbances, which would long condition their subsequent efficiency in so complex a field of work as science. The net result would be a grave loss to society in the services of one of its most important groups.

The problems associated with full employment of scientists are not at all insoluble, provided the attempt to solve them is made against a general background of an economy of plenty. Just as the demands of war have caused an almost complete mobilization of scientists to deal with war problems, so would the many and more complex demands of such a peacetime economy bring about the full employment of scientists. A nation that has seen the value of mobilizing its scientists for war will also want to make the greatest use of science during a peacetime of plenty. Scientists themselves, having experienced what can be accomplished under the stimulus of war, will not be satisfied with any lessened utilization and support of science.

With the problem surveyed in this light, it is easy to see several solutions:

1. Every effort should be made to maintain in operation all or most of the research centers that have developed during the war and to put them to use for peacetime scientific activities. Many of these centers, such as the Naval Medical Research Institute and the Radio Research Laboratories, should be able to convert to peacetime problems without any delay, given the money and the authorization. Other laboratories will require longer periods to change over. It is not too much to expect American scientific and administrative ability to carry the process through successfully in three to twelve months. Project directors and research workers should be invited to present programs along which their organized project facilities may become useful in peacetime research. At the same time universities and other institutions should be encouraged to expand their research programs and their science departments. Such steps will require considerable Federal assistance in planning and financing. Immediate legislation is imperative to empower and finance appropriate steps. A Federal Office of Scientific Development with sufficient funds and with powers to plan and allocate activities is urgently needed for the immediate postwar period.

2. The proposed Office of Scientific Development should also be empowered to assist research programs in industrial laboratories and to help maintain research activities, particularly among the smaller firms. The various phases of this problem should be tackled immediately by scientists and legislators. For example, this step may have to be surrounded with appropriate safeguards to guard against monopolistic misuse.

3. We shall have to adopt some policy regarding the postwar use of Federally owned war plants. If they are to be maintained as going concerns producing peacetime products (an outcome generally to be desired), they will be able to keep employed the scientists now working in them. Probably their demand for scientists would increase, for a program of reconversion and a search for new products and markets would certainly involve a program of research.

4. Where laboratories, whether Federal, OSRD, university, or industrial, will have to release scientists from wartime jobs, severance pay ought to be established. This pay is now customary in certain professional fields (e.g., journalism) and under the contract agreements of many industries. It is a recognition by the employer of the hardships imposed on the discharged employee and an effort to aid him in tiding over until reemployment. In my opinion the severance pay of scientists should be graduated to take into account a variety of factors, such as his prospects of immediate re-employment, degree of wartime removal from his peacetime work, the extent of his wartime migration, and his family needs. The sum probably should amount to three to twelve months' salary.

5. Special efforts should be made to facilitate the return of scientists to work that was discontinued at the change-over into war research. These activities will involve reassembly of staffs (the National Roster should play an important and continuing part), aid in reconverting physical plant of laboratories, and aid in stimulating return to peace problems. Much scientific equipment will become available when projects are discontinued. Through special arrangements with the administrators of Government surplus

property this equipment could be made available to re-equip laboratories, thus preventing waste or depreciation of much of it in government warehouses. Some surplus equipment could probably be sent to equip laboratories in China, India, and in the devastated countries of Europe. To stimulate the formulation of peacetime programs it would be useful to increase temporarily the frequency of local and national scientific meetings. At the earliest practicable time international scientific meetings should be planned.

Rehabilitation and Retraining

The great wartime shifts that have taken place among scientists carry in their wake important problems which will arise during reconversion to peace.

1. Some scientists are in the Armed Forces as soldiers or as technicians in fields other than those of their specialized scientific training. They have been out of contact with the progress of their professions, with literature, and with their colleagues. These contacts need to be restored.

2. Many other scientists have shifted from their normal peacetime fields into more or less distant branches of science. Their contacts with their own fields have been weakened or broken and will need to be renewed. After the war some of these persons will wish to remain in their new fields, and they will require a considerable amount of additional training to round out that received in wartime.

3. Where scientists have remained in their normal fields of activity in their war work, migrations often resulting in loss of contact with scientific libraries, wartime curtailment of scientific meetings, breakdown of international communications, secrecy or other restrictions on publication, and the rigors of full-time concentration on war problems requiring immediate solutions have caused a fragmentation of the bonds that knit scientists closely together and make possible the interplay of ideas leading to scientific progress.

4. Finally, there is a large group of younger people, many of whom have received somewhat hasty, concentrated, and specialized training, while others have had only partial training in certain specialized branches of science. This group of younger scientists has become a very important one, especially in some of the newer industries. They will want and deserve a more rounded scientific education, particularly to develop contacts with other laboratories in order to learn a variety of techniques and viewpoints. This group includes many military physicians, who are practicing at present a specialized form of medicine and to whom medical research facilities have been denied.

To solve the foregoing problems a comprehensive program is needed. Again it is the Federal Government that will have to be called upon to act in collaboration with the professional societies and with the universities and other research centers. A retraining program would be a boon to scientists, to the teaching centers that offer the training, and to the nation, which would get a body of scientists whose recent practical experience in applied wartime science would be reinforced by fresh training in their professional fields. Funds and organizational initiative are the main requisites for the establishment of fellowships and traveling scholarships, to provide special courses and meetings, and to publish currently the results of research.

Another phase of postwar training should be the reorganization of our educational setup from top to bottom, including the reeducation of teachers in line with the educational plan they would be required to administer. During the emergency situation of the war our educational system has been found deficient in certain directions. All along the line, from the elementary schools to the highest institutions, we have found mathematics, sciences, and languages neglected, or inadequately taught. As a result some inductees could not cope with the problems of a mechanized, technologically advanced army. To satisfy their needs the Armed Forces have become a great center of scientific education at all levels, even undertaking organization of pre-induction training.

The failure of our educational system to provide a modern form of education has been due principally to skimping of funds that would provide facilities and hire teachers.

Largely it is a failure to formulate an adequate educational policy for the entire nation. To prepare for a peace that is to bring with it an expanded industrial activity based upon the applications of technological advances to the welfare of the entire world, the lessons of wartime should be grasped thoroughly.

Our educational system will therefore have to be expanded and revamped to teach more mathematics, languages, and sciences, and to teach them more intensively than heretofore. These changes should not be made at the expense of sound cultural and civic training. Therefore, the educational schedule will have to undergo really far-reaching revisions that will permit the student to learn more easily a larger number of subjects. This is both a challenge and an opportunity to teachers in general and to teachers of science in particular. Again it appears that Federal funds will have to be devoted to this task, and, since the job of developing and implementing a new program will take time, it should be started immediately. The co-operation of scientists, educators, and the Government is required for this task. Reference is made to the excellent work of the Cooperative Committee on Science Teaching, detailed in its reports and in articles published by its members.

In some specialized fields of education the war has disclosed very serious bottlenecks. I refer particularly to the dental, medical, and technological fields in which many scientists make their livelihood as teachers. For the past decade medical schools have turned out about 5,000 physicians annually. New dentists probably number less than 2,000 a year; the technological graduates about 10,000 annually. In the course of the war we have witnessed acute shortages of all these highly trained practitioners of the sciences, who cannot be turned out in less than three to five years' specialized training.

Prewar limitations on the number of students were largely due to the unplanned nature of our economy. To some extent limitations were imposed consciously in the interest of monopolistic control of the professional fields. Whatever their causes, these limitations have been effected in several ways. The number of schools has been limited and essentially static for a long time. Some medical schools, for instance, receive applications from ten or more times as many students as they can accommodate. This has given scope to rigorous selection and exclusion of students, often on a basis of scholastic merit but often also on the basis of many extraneous factors. Negroes are admitted to only a few medical schools, and then in limited numbers. They have difficulty in breaking into other professions as well. The number of women admitted into professional schools is small and in some they are entirely excluded. Jews have been excluded from, or limited in their admission to, all types of professional schools. Discriminatory control has been exercised also at stages beyond the schools. Engineering firms have made it a practice not to hire, or to restrict the number of, Jews, Negroes, or women, as the case might be. Hospitals have discriminated against "unwanted" categories in making appointments to internships, residencies, or staff appointments. Similar practices are common in graduate schools and are generally accompanied by discrimination when appointments to university or laboratory positions are made.

For the postwar world we can envisage the need for a great number of American, British, and Soviet technologists, public health experts, and scientists who would be called upon to carry modern scientific achievements not only to the people of their own lands, but also to the peoples of vast unindustrialized areas, such as are found in China, India, and the African and South American continents. We can judge the possibilities of an expanding economy by recalling that the Soviet Union trains about 25,000 physicians annually (more than half of them women), against our fixed number of about 5,000, and trains technologists in other fields in proportion. If for no other reason than to satisfy the needs of a postwar economy such as has been envisaged, the barriers against women, Negroes, and Jews will have to be torn down. This will help to supply the student body but not the physical facilities. Schools will therefore have to be expanded and new ones built. A national program of stipends for students who meet specified scholastic standards will also be needed

to enable the talented children of poor parents to use their abilities in the national welfare.

A program of expanded professional and scientific training will of necessity bring about a greater demand for teachers, with a concomitant increase in the faculties and student bodies of the university science departments. To make the profession of science teaching more attractive a better standard of salaries and more research opportunities will have to be granted to science teachers.

Standards of Living

Although the scientist traditionally has been paid far below the value of his training and his contributions to society, his standards for living are high. He spends a large share of his income for education, insurance, and health protection. His social milieu makes considerable demands on him for housing, dress, entertainment, and the like. He is expected to maintain cultural contacts, with attendant expenditures for books, magazines, the theater, and concerts. There are certain professional expenses: membership dues in societies, expensive technical books and periodicals, and costs of attending scientific meetings. Sometimes he even has to pay part of the cost of publishing the results of his researches.

His demands are relatively modest, but the unsatisfactory level of his prewar salary will have to be readjusted. Primarily, however, he will want full employment of his skills and the knowledge that his scientific contributions are utilized as fully as possible to enable the nation and the entire world to achieve standards of living and happiness unbelievably higher than those now prevailing. Insistence by scientists and the public on immediate and full-scale application of scientific advances will be an important factor in the postwar world. In our country alone there would be a tremendous rise in our relatively high standard of living by the adoption of a comprehensive program of public health and preventive medicine; by the immediate postwar application of new technologies in metals, plastics, and synthetic fibers; by the utilization of engineering advances in design and construction of power units such as the airplane, automobile, and stationary motors; by making available cheap supplies of chemicals, fertilizers, metals, and biologicals, and by the development of new and old cultural resources—among them frequency modulation, television, and color printing processes.

The scientist will expect to share fully in this increase of the general standard of living. He will want better postwar educational facilities for his children and the assurance that he and his family will have job security and security against old age and disease, in common with the rest of the nation.

There are signs that scientists are prepared to organize themselves to secure these benefits. The Federation of Architects, Engineers, Chemists, and Technicians; the State, County, and Municipal Workers; the United Federal Workers, and the United Office and Professional Workers number scientists among their members, as does the American Federation of Teachers, and other industrial unions. Several independent unions are also in existence, and the larger technical societies are beginning to consider the economic problems of their members. That scientists can benefit from trade union membership has been clearly shown in Great Britain and in other parts of the British Commonwealth. The Association of Scientific Workers in Great Britain rose from a mere 2,000 members to almost 25,000 two years after it had become a trade union. Recent polls in Canada held by various professional societies have shown that the large majority of Canadian scientists desire to have collective bargaining agreements with their employers.

International Collaboration

The results to be expected from international collaboration in the scientific, cultural, industrial, and political spheres have already seen stated. The immediate problems of international scientific co-operation are quite specific, being determined by the war we are fighting and the peace we aim to achieve.

1. It is necessary to have the closest possible collaboration among the Allies in the field of scientific activities as well as in the military, economic, and political spheres. To a certain extent this collaboration has

been achieved with some countries, particularly with Great Britain and the Dominions, where our Government maintains special scientific missions. Contacts with the Soviet Union and with China are more sporadic and occur chiefly through unofficial channels. The British, on the other hand, maintain much closer contacts with the scientists of China (for example, the noted biologist Joseph Needham is a scientific adviser in Chungking) and with those of the Soviet Union. Britain is also the haven of many refugee scientists from the occupied countries. These refugees have even established complete university facilities in Britain.

All the United Nations no doubt would benefit from the interchange of scientific missions. Our Government is in a position to take the lead in establishing such missions formally. Some useful results would be achieved also by contacts between the professional societies of the various nations. A beginning has already been made in establishing such contacts between the United States and the Soviet Union through the Science Committee of the National Council of American-Soviet Friendship and the American-Soviet Medical Society, both of which should receive even more support from scientists and the general public.

Several examples of the usefulness of such collaboration may be cited here. Joffe, the well-known physicist, has reported in an article received by the American Association of Scientific Workers that the Soviet Union now possesses photocells twenty times more sensitive than the similar types used in our country, and metallic rectifiers with one hundred times the current capacity of the selenium and copper oxide types. Elsewhere he has stated that Soviet physicists had developed airplane detection and ranging devices before even the British.

2. We are fighting in company with many small countries, as well as with colonial or industrially undeveloped nations. Our science and knowledge will have to come to their aid in solving their special problems. This is now taking place as a wartime measure in Latin America, India, and China. Much more can be done to bring the latest technological and scientific advances to these peoples. Regular channels should be established for exchange of students, teachers, and literature. Anything we can do in this direction will reciprocally benefit our own country as well, sometimes even to an extent larger than our contribution abroad.

3. A vast problem is happily coming ever nearer—the problem of reconstructing the cultural institutions devastated in the territories occupied by the fascists. The task of rebuilding and restocking laboratories, libraries, and other institutions will have to be undertaken largely by the United States. We must not stint our establishment of the concrete and living symbols of international friendship and collaboration. To approach this task it is necessary to set up a "cultural UNRRA" with adequate funds and comprehensive plans. Scientists and educators of the United Nations are already making some plans for this, but it would be well to bring in the general public and the body of scientists to help in planning and to demand early execution of these plans.

4. In the postwar period science will play a larger role than ever in shaping the world, and more consciously. Scientists will therefore require a larger share than they now have in formulating and determining international (and national) policies. Further, since these policies will have a great deal to do with the industrialization and growth of the undeveloped parts of the world, there will have to be a high degree of collaboration among scientists of all countries. Thus the need is indicated for formal governmental actions to set up a permanent world scientific body on the order of the old League's International Labor Office, but tied to the international body proposed at Dumbarton Oaks.

5. Science can be a powerful force both in the present struggle against fascism and in the postwar development of a world organization. At present, for example, scientists can support their governments in the fight against fascism on the intellectual and cultural fronts. This is a particularly important activity because scientists can speak with authority on many phases of fascist dogma and because they are respected by their lay countrymen. University people have been in the forefront of the fight for democracy and national unity in China. The traditions of the European universities as

centers of liberalism and progress were sustained in Loyalist Spain, and many of Spain's scientists are now refugees. These traditions have been carried over into the Latin American countries.

A particularly stirring example of this liberalism occurred on October 13, 1943, when one hundred and fifty of Argentina's most eminent citizens in all walks of life issued a "Declaration of Effective Democracy and American Solidarity" calling for a return of Argentina to its constitutional government and the exercise of effective democracy. "Argentina cannot and should not," the statement said, "apply only a part of her constitution and live isolated or estranged from her brother peoples of America and from those of the world fighting for democracy." Among the signers of this Declaration were some of Argentina's leading professionals and scientists, including South America's most eminent scientist Bernardo A. Houssay, professor of physiology at Buenos Aires and the only Latin American Nobel prize winner in science.

When the government of Argentina took punitive measures by dismissing all signers of this Declaration who were connected with any public office (including all the university professors) the American Association of Scientific Workers protested through a message sent to Secretary of State Cordell Hull on February 21, 1944.

A copy of this statement was sent to the Argentine Embassy. Sr. Ernesto C. Uriburu replied that "it is unfortunate that events of an entirely domestic character are used as instruments of discord among friendly nations." This type of reply is reminiscent of Nazi arguments that their persecution of German nationals was a "domestic matter." The American Association of Scientific Workers has since that time received further reports of continued persecution and coercion of scientists, educators, and students by the Argentine Government. On January 11, 1945, we accordingly sent another letter to the Secretary of State asking that immediate steps be considered at the forthcoming conference of American republics in Mexico City, which might lead to strong and concerted action by the United Nations against these manifestations of Argentine fascism.

Another recent action of the American Association of Scientific Workers, undertaken as part of the fight against fascism, has had considerable repercussions. I refer to the pamphlet *The Races of Mankind* by Ruth Benedict and Gene Weltfish. In the summer of 1942 the National Office of the Association began to receive disquieting reports of the inroads that fascist racist propaganda was making into our national morale and fighting unity. Success of such propaganda on the home front would have endangered our war production. With our troops then beginning to go overseas into many strange lands, it was felt that relations between our men and the native populations might become endangered. Accordingly, I suggested to the New York branch of the Association that it prepare a pamphlet on the races of mankind, that branch being chosen because it numbered several prominent anthropologists among its members. The pamphlet which resulted is the product of a committee of experts in several allied fields and has become one of the most popular publications of the war.

Originally intended for and approved by the USO, its publication and distribution by that agency was stopped by Chester I. Barnard, president of USO, despite his admission to me that the pamphlet "is acceptable and perhaps regarded as desirable in the view of at least most of our Member Agencies." *The Races of Mankind* was then published by the Public Affairs Committee and was distributed to service men and women by the YMCA, one of the Member Agencies of USO, until Mr. Barnard forbade this also. It is worthy of note that Mr. Barnard's actions regarding *The Races of Mankind* were followed by a similar ban on the distribution of *The Good Soldier Schweik,* Hasek's democratic classic of the last war. This ban seems to have been imposed because Hasek makes jibes at Austrian military chaplains, which apparently offended some Catholics. Unless USO reverses its present trend, there is danger that it may become a social workers' "Hays Office," accumulating an *index expurgatorius* that will include anything distasteful to the most sensitive fundamentalists of all faiths and social doctrines.

More recently 55,000 copies of *The Races*

of Mankind were purchased by the Army Morale Division for use by officer-instructors as "background material to help counteract the Nazi theory of a super-race." (This quotation is from a Congressional report.) Chairman May, of the House Military Affairs Committee, then threatened to "expose the motives behind this book," and the Army stopped its distribution. A subcommittee of the House Military Affairs Committee, which was headed by Representative Durham of North Carolina (representing the Chapel Hill district) later issued a "report" which was chiefly concerned with red-baiting the members of the Public Affairs Committee that had published the booklet. Ordway Tead, Harry Gideonse, Lyman Bryson, George Soule, Maxwell Stewart, Beulah Amidon, Raymand Leslie Buell, and Luther Gulick are among the individuals thus attacked. A sample of the report, which gives its general tenor is the following: "Toward the end of the booklet the authors drop anthropology for politics, sociology, labor unionization, and similar subjects employed by propagandists of communism. It winds up with a challenge, in which respect it follows a basic technique characteristic of communistic literature. . . ."

Despite these attacks *The Races of Mankind* has already become a classic in the fight for interracial amity in our country, with more than 500,000 copies in circulation. In deciding to undertake wide distribution of *The Races of Mankind* among service men and women the National CIO War Relief Committee declared: "We feel this pamphlet is one of the best weapons in the hands of our soldiers. It certainly is one of the best answers to Hitler's Aryan creed. It promotes tolerance by showing the brotherhood of mankind, the likeness and fundamental unity of the races. It states that the cure for race prejudice lies in freedom from fear. It emphasizes one of the fundamental principles for which our men and women in the armed forces are fighting."

Through activities of the American Association of Scientific Workers and of other sections and societies affiliated with the American Association for the Advancement of Science which emphasize the social relationships of science and which bring scientists into closer contact with the problems that face society, scientists will come to play an increasing part in building the world envisaged by the Teheran agreement.

I have outlined some of the problems that face scientists immediately and in the postwar period. I have tried to indicate solutions for some specific situations. Basically these solutions call for considerable national and international governmental action in the way of organizing, co-ordinating, and financing. Various proposals of this sort have in the past been attacked as "regimentation." The trend of modern life, however, calls more and more on central, organized action to provide an ever-widening array of services that society is finding essential to its well-being. It is clear that the development of science and of knowledge is one of these essentials.

The more scientists and their societies realize that they must co-operate with government—and with each other—in making these plans, the greater will be the opportunity for their individual ideas to enter into the final working arrangements. Thus far there has been a serious rift among scientists. While some have advocated the course outlined above, others have followed a rather inconsistent policy. They have accepted funds poured out by the Government and have asked for more, while denying the Government's right or ability to exercise some measure of control in the public interest. The latter group has therefore been merely critical rather than constructive concerning attempts to develop large scale financing and planning in the scientific sphere. For instance, the Kilgore Bill to set up an Office of Scientific and Technical Mobilization has been violently attacked, and usually unfairly, by the major scientific societies. Yet the need for postwar planning and finance of science and technology is so patent that various modifications of the original bill are receiving support from many individual scientists and other progressive forces in our country. In Congress, too, these postwar plans have been gaining support. The scientific societies will therefore be forced to abandon their special form of "isolationism" and to take part in formulating plans based on the recognition of certain great responsibilities that science bears to society. Failing

this, society will itself take the necessary steps and impose them on the structure of science in our country.

A highly important step was taken by President Roosevelt in his letter to Dr. Vannevar Bush, director of OSRD, which was released on November 21, 1944, and published in *Science* on December 15, 1944. In his letter, the President asked Dr. Bush and his associates to provide answers on four important questions relating to the future of American science:

1. How can the results of war research be best made known so that they may be used to "stimulate new enterprise, provide jobs . . ., and make possible great strides for the improvement of the national well-being?"

2. "What can be done now to organize a program for continuing in the future the work which has been done in medicine and related sciences?"

3. "What can the Government do now and in the future to aid research activities by public and private organizations? The proper roles of public and of private research, and their interrelation, should be carefully considered."

4. "Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?"

The President prefaced his questions with well-deserved praise for the work of OSRD, much of which is still hidden in the interests of military security. He stated: "There is, however, no reason why the lessons to be found in this experiment can not be profitably employed in times of peace. The information, the techniques, and the research experience developed by the Office of Scientific Research and Development and by the thousands of scientists in the universities and in private industry, should be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living."

The President's action is far-sighted and its terms are sufficiently broad to make feasible a comprehensive plan for postwar science in our country. Professors Mather, Phillips, and I have formulated certain proposals on the President's directive to Dr. Bush, which are to be published elsewhere and which are intended to initiate public discussion both by the scientific public and by leaders in the legislative and industrial fields in our country. (See *The Future of American Science* by Kirtley F. Mather, Harry Grundfest, and Melber Phillips, published in New York by the U.O.P.W.A.) We have done so in full appreciation of the magnitude of the task and opportunity that Dr. Bush and his colleagues face in formulating a wise and public spirited program for science, and we have urged our fellow scientists to put their experience and views at the service of Dr. Bush and his associates.

Highly important, too, is the President's request for early action on the various points raised in his letter. He stated: "I hope that, after such consultation as you may deem advisable with your associates and others, you can let me have your considered judgment on these matters as soon as convenient—reporting on each when you are ready, rather than waiting for completion of your studies in all." This request makes it possible for the several parts of the program to be put into effect as quickly as possible, rather than wait until every item is fitted in and every difficulty or controversy is straightened out.

In other countries, too, scientists and governments have begun to lay postwar plans. The Association of Scientific Workers in Great Britain held an epoch-making Conference on the Planning of Science a year ago, with Government Ministers and other leaders as important participants. More recently it has issued a comprehensive "Post-War Policy for Science." In May 1944 the Australian Association of Scientific Workers also held a conference on scientific plans for that country. Various branches of the American Association of Scientific Workers have been working on its own program, which should be issued shortly.

Growing readiness of American scientists to participate with other professional colleagues in formulating postwar plans has recently been indicated by the increased participation of scientific societies in the second National Wartime Conference, as compared with their participation in the first. Among

the participants were the American Academy of Pediatrics, the American Association for the Advancement of Science, the American Association of Scientific Workers (one of the initiators of this Conference), the American Dental Association, the American Medical Association, the American Psychological Association, and the American Sociological Society. The success of this conference also revealed a new factor—the growing recognition of the fundamental unity of the professional, cultural, and white collar workers of this country.

This growing realization of the need for unity with similar groups in other fields of endeavor, and the need for action to formulate and to press for a long term program was aptly indicated in a statement that was made to the conference by a great scientist and a great citizen of the world, Albert Einstein:

> I consider it important, indeed urgently necessary, for intellectual workers to get together, both to protect their own economic status and also, generally speaking, to secure their influence in the political field.
>
> On the first-mentioned, the economic side, the working class may serve us as a model: they have succeeded, at least to some extent, in protecting their economic interests. We can learn from them too how this problem can be solved by the method of organization. And also, we can learn from them what is our gravest danger, which we ourselves must seek to avoid: the weakening through inner dissensions, which, when things reach that point, make cooperation difficult and result in quarrels between the constituent groups.
>
> But again, we can also learn from the workers that limitation to immediate economic aims, to the exclusion of all political goals and effective action will not suffice either. In this respect, the working classes in this country have only begun their development. It is inevitable, considering the progressive centralization of our production, that the economic and the political struggle should become more and more closely interwoven, the political factor growing in significance in the process. In the meantime the intellectual worker, due to his lack of organization, is less well protected against arbitrariness and exploitation than a member of any other calling.
>
> But intellectual workers should unite, not only in their own interest but also, and no less importantly, in the interest of society as a whole. For division among intellectuals has been partly to blame for the fact that the special parts and the experience which are the birthright of these groups have so seldom been made available for political aims. In their room, political ambition and desire for profit almost exclusively determine events, instead of professional knowledge and judgment based on objective thinking.
>
> An organization of intellectual workers can have the greatest significance for society as a whole by influencing public opinion through publicity and education. Indeed, it is its proper task to defend academic freedom, without which a healthy development of democracy is impossible.
>
> An outstandingly important task for an organization of intellectual workers at the present moment is to fight for the stablishment of a supra-national political force as a protection against fresh wars of aggression. It seems to me that the selection of a particular plan for an international government should not, at the present moment, be our chief aim. For if there existed, among the majority of our citizens, the firm intention of establishing international security, the technique of giving shape to such an instrument would not present an all-too-difficult problem. What is lacking in the majority is the conviction, founded on clear thinking, that there is no other means of permanently avoiding catastrophes like the present one. In the organization and promotion of enlightment on this subject, I see the most important service which an organization of intellectual workers can perform at this historic moment. Only by means of setting energetically about such a task can an organization like the one here planned achieve inward strength and outward influence.

In the light of this eloquent statement, it is not surprising that the second National Wartime Conference closed only after a spontaneous demand among the delegates had resulted in plans for a permanent federation of the professional organizations to act as a clearing house for common problems and experiences and as a medium for making these problems and demands known to the general public and to the legislative and executive branches of the Government. The National Council of Professional Organizations and the more recently formed Independent Citizens' Committee of the Arts, Sciences and Professions are manifestations of the readiness of scientists and other professional and intellectual workers to participate more fully in formulating and determining the national policies of a democracy.

THE AUTONOMY OF SCIENCE*

By M. POLANYI

TO-DAY the position of science which was unquestionably accepted in the Western countries for the last 300 years or so, has been challenged by an authoritarian doctrine.

It is difficult to trace a complete authoritative statement of the argument used in support of the state control of science. But I believe that in its most precise form this argument would run about as follows. "No scientific statement is absolutely valid, for there are always some underlying assumptions present the acceptance of which represents an arbitrary act of faith. Arbitrariness prevails once more when scientists choose to pursue research in any one direction rather than another. Since the contents of science, and the progress of science both vitally concern the community as a whole, it is wrong to allow decisions affecting them to be taken by private individuals. Decisions, such as these, should be reserved to the public authorities who are responsible for the public good. It follows that both the teaching of science and the conduct of research must be controlled by the State."

I believe this reasoning to be fallacious and its conclusions to be wrong. Yet I shall not try to meet the argument point by point, but will instead oppose it as a whole by analyzing the actual state of affairs which it profoundly misrepresents. I shall survey the individuals and groups who normally make the decisions which contribute to the growth and dissemination of science. I shall show that the individual scientist, the body of scientists and the general public, each play their part and that this distribution of function is inherent in the process of scientific development, so that none of these functions can be delegated to a superior authority. I shall argue that any attempt to do this could only result in the distortion—and if persisted in—in the complete destruction of science. I shall demonstrate instances where such attempts have actually been made and the destruction did actually come to pass.

THE primary decisions in the shaping of scientific progress are made by individual investigators when they embark on a particular line of inquiry. To-day in science the independent investigator is usually a professional scientist, appointed by public authorities in view of his scientific record, to a post where he is expected to do research. For this he is given freedom to use his own time and is often also given control over considerable means in money and personnel.

The granting of such discretion to individuals for the purposes of their profession is fairly common in all departments of life. Holders of higher posts in Business, Politics, the Law, Medicine, the Army, the Church, are all invested with powers which enable them to follow their own intuitive judgment within the framework of certain rules. They use this freedom in order to discharge their duties. Yet the degree of independence granted to the scientist may appear to be greater than that allowed to other professional men. A businessman's duty is to make profits, a judge's to find the law, a general's to defeat the enemy; while in each case the choice of the specific means for fulfilling their task is left to the judgment of the person in charge, yet the standards of success are laid down for them from outside. For the scientist this may not hold quite to the same extent. It is part of his commission to revise and renew by pioneer achievements the very standards by which his work is to be judged. He may be denied full recognition for a considerable time—and yet his claims may be ultimately vindicated. But the difference is only one of degree. All standards of professional success undergo some change in the course of professional practice, and on the other hand even the most daring pioneer in science accepts the general conceptions of scientific achievement and bases his scientific claims essentially on traditional standards.

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I shall have more to say in this connection later.

In any case the powers to use his own intuitive judgment and the encouragement to embark on original lines of inquiry are not given to the scientist to enable him to exercise his own personal wishes. The high degree of independence that he enjoys is granted only to enable him to discharge the more effectively his professional obligations. His task is to discover the opportunities in the given state of science for the most successful application of his own talents and to devote himself to the exploitation of these openings. The wider his freedom, the more fully can he throw the force of his personal conviction into the attack on his own problem.

At the start his task is yet hidden, but it is none the less definite. There is ample evidence to show that at any particular moment the next possibilities of discovery in science are few. The next step to be taken in any particular field is in fact sometimes so clear that we read of a "dramatic race" between leading scientists for an impending discovery. A series of such races took place within a period of a few years for the discovery of the synthesis of various vitamins. In 1935 Karrer in Zürich and Kuhn in Heidelberg competed in the synthesis of Vitamin B_2. In 1936 three teams, Andersag and Westphal in Germany, Williams and Cline in the United States and Todd and Bergel of England raced for the synthesis of Vitamin B_1. And in 1938 one of the participants in the B_1 race, Todd, and one in the B_2 race, Karrer, rivalled closely in the synthesis of Vitamin E. Only a few years earlier (1930) a great race was won in physics when Cockcroft and Walton working under Rutherford's guidance in Cambridge accomplished the artificial disintegration of the atom by electric discharge—ahead of Lange and Brasch in Germany and Breit, Tuve, Hafstad, Lauritsen, Lawrence and others in America. Or to take an example in pure theoretical physics: between 1920 and 1925 the standing problem of theoretical physicists was the reconciliation of classical mechanics and quantum theory; and around the year 1925 a number of physicists (de Broglie, Heisenberg, Born, Schrödinger, Dirac) did actually discover—more or less independently—the various parts of the solution. In a review of Eve's biography of Rutherford, Sir Charles Darwin estimates roughly by how much Rutherford may have anticipated his contemporaries with his various discoveries and suggests for most cases spans of time ranging from a few months to three or four years. Rutherford himself is quoted as saying that no one can see more than an eighth of an inch beyond his nose and that only a great man can look even as far as that.

Scientific research is not less creative and not less independent, because at any particular time only a few discoveries are possible. We do not think less of the genius of Columbus because there was only one New World on this planet for him to discover.

Though the task is definite enough, the solution is none the less intuitive. It is essential to start in science with the right guess about the direction of further progress. The whole career of a scientist usually remains linked to the development of the single subject which stimulated the early guess. All the time the scientist is constantly collecting, developing and revising a set of half-conscious surmises, an assortment of private clues, which are his confidential guides to the mastery of his subject.

This loose system of intuitions can not be formulated in definite terms. It represents a personal outlook which can be transmitted only—and only very imperfectly—to personal collaborators who can watch its daily application for a year or two to the current problems of the laboratory. This outlook is as much emotional as it is intellectual. The expectations which it entertains are not mere idle guesses but active hopes filled with enthusiasm.

The emotions of the scientist also express and uphold the values guiding research; they turn with admiration to courage and reliability and pour scorn on the commonplace and the fanciful. Such emotions again can be transmitted only by direct contact in the course of active collaboration. They are in fact the very life-blood of collaboration in a research school. Its leader has no more important function than to maintain enthusiasm for research among his students and instil in them the love of his own particular field.

Such is the calling of the scientist. The state of knowledge and the existing standards of science define the range within which he must find his task. He has to guess in which field and to what new problem his own special gifts can be most fruitfully applied. At this stage his gifts are still undisclosed, the problem is yet obscure. There is in him a hidden key capable of opening a hidden lock. There is only one force which can reveal both key and lock and bring the two together: the creative urge which is inherent in the faculties of man and which guides them instinctively to the opportunities for their manifestations. The world outside can help by teaching, encouragement and criticism, but all the essential decisions leading to discovery remain personal and intuitive. No one with the least experience of a higher art or of any function requiring higher judgment could conceive it to be possible that decisions such as these could be taken by one person for another. Decisions of this kind can in fact only be suppressed by the attempt to transfer them to an outside authority.

The scientist to-day cannot practise his calling in isolation. He must occupy a definite position within a framework of institutions. A chemist becomes a member of the chemical profession; and a zoologist, a mathematician or a psychologist, each belongs to a particular group of specialised scientists. The different groups of scientists together form the scientific community.

The opinion of this community exercises a profound influence on the course of every individual investigation. Broadly speaking, while the choice of subjects and the actual conduct of research is entirely the responsibility of the individual scientists, the recognition of claims to discoveries is under the jurisdiction of scientific opinion expressed by scientists as a body. Scientific opinion exercises its power largely informally but partly also by the use of an organised machinery. At any particular time only a certain range of subjects is deemed by this opinion to be profitable for scientific work. Accordingly no training is given and no posts either for teaching or for research are offered outside these fields, while existing research schools are specialised in these subjects and so are the journals available for publication.

Even within the fields that are recognised in this sense at any particular time, scientific papers cannot be published without preliminary approval by two or three independent referees, called in as advisers by the editor of the journal. The referees express an opinion particularly on two points: whether the claims of the paper are sufficiently well substantiated and whether it possesses a sufficient degree of scientific interest to be worth publishing. Both characteristics are assessed by conventional standards which in fact are changed from time to time according to variations of scientific opinion. Sometimes it may be felt that the tendency among authors is towards too much speculation which the referees will then try to correct by imposing more discipline. At other times there may seem to be a danger of absorption in mere mechanical work, which referees will again try to curb by insisting that papers should show more originality. Naturally, at different periods there are also marked variations as regards the conclusions that are considered sufficiently plausible. A few years ago there was a period in which it was easy to get a paper printed claiming the transformation of chemical elements by ordinary laboratory processes; to-day—as in earlier times—this would be found difficult, if not altogether impossible.

The referees advising scientific journals may also encourage those lines of research which they consider to be particularly promising, whilst discouraging other lines of which they have a low opinion. The dominant powers in this respect are however exercised by referees advising on scientific appointments, on the allocation of special subsidies and on the award of distinctions. Advice on these points, which often involve major issues of the policy of science, is usually asked from and tendered by a small number of senior scientists who are universally recognised as being the most eminent in a particular branch. They are the chief Influentials, the unofficial governors of the scientific community. By their advice they can either delay or accelerate the growth of a new line of research. New facilities for work can be most rapidly made available by the granting at their command of special sub-

sidies for research. By the award of prizes and of other distinctions they can invest a promising pioneer almost overnight with a position of authority and independence. More slowly, but no less effectively, a new development can be stimulated by the policy pursued by the Influentials in advising on new appointments. Within 10 years or so a new line of thought may be established by the selection of appropriate candidates for Chairs, which have fallen vacant during that period. The same end can be promoted by the setting up of new Chairs, which sometimes replace others which have become obsolete.

The constant re-direction of scientific interest by the leaders of scientific opinion fulfils the important function of keeping the standards of performance in different branches of science approximately at an equal level. In the various branches the standards of reliability and systematic interest are applied in somewhat different ways. In general, the greater the human interest of the subject matter, the less rigorous the tests required for establishing the same standard. Living beings are intrinsically more interesting than inanimate nature. Scientific statements will be allowed to be less definite and less certain if made about plants or animals than about minerals or stars. Similarly a speculative achievement of modest range may be recognised as a success if it relates to the problems of living matter. The leaders of scientific opinion have to adjust the different standards in such a manner as to maintain in every field a uniform level of development. This level being jointly characterised by the intrinsic interest of the subject matter, the profundity or systematic interest of the generalisations involved and the precision and certainty of the new statements made.

The steady equalisation of standards in all branches is necessary, not only in order to maintain a rational distribution of resources and recruits for research schools throughout the field of science, but also in order to uphold equally in every branch the authority of science with regard to the general public. With the relation of science and the public I shall presently deal in some detail. But a particular aspect of it requires mention at this stage since it involves the final phase of the process by which recognition is given to new scientific claims. Published papers are open to discussion and their results may remain controversial for some time. But scientific controversies are usually settled—or else shelved to await further evidence—within a reasonable time. The results then pass over into textbooks for universities and schools and become part of generally accepted opinion. We note that this final process of codification is again under the control of the body of the scientific opinion—expressed by reviewers—under whose authority text-books are in fact brought into circulation.

The standards of science—like those of all other arts and professions—are transmitted largely by tradition. Science in the modern sense originated some 300 years ago from the work of a small number of pioneers, among whom Vesalius and Galileo, Boyle, Harvey and Newton were pre-eminent. The founders of modern science have discussed extensively and with considerable insight the new methods which they applied; moreover the doctrines of the contemporary philosophy—particularly through John Locke—gave full expression to their outlook. Yet the core of the scientific method lies in the practical example of its works. Whatever the various philosophies of the scientific method may still reveal, modern science must continue to be defined as the search for truth on the lines set by the examples of Galileo and his contemporaries. No pioneer of science, however revolutionary—neither Pasteur, Darwin, Freud nor Einstein—has denied the validity of that tradition nor even relaxed it in the least. The great succession of men of genius to whose creative powers science has given scope since the end of the sixteenth century, has not overshadowed the first pioneers but has—on the contrary—increasingly revealed the implications of their discoveries and thus added ever more brilliance to their achievements.

Modern science is a local tradition and is not easily transmitted from one place to another. Countries such as Australia, New Zealand, South Africa, Argentina, Brazil, Egypt, Mexico, have built great modern cities with spacious universities, but they have rarely succeeded in founding important schools of research. The total current scientific production of these countries before the

war was still less than the single contributions of either Denmark, Sweden or Holland. Those who have visited the parts of the world where scientific life is just beginning know of the backbreaking struggle that the lack of scientific tradition imposes on the pioneers. Here research work stagnates for lack of stimulus, there it runs wild in the absence of any proper directive influence. Unsound reputations grow like mushrooms: based on nothing but commonplace achievements, or even on mere empty boasts. Politics and business play havoc with appointments and the granting of subsidies for research. However rich the fund of local genius may be, such environment will fail to bring it to fruition. In the early phase in question New Zealand loses its Rutherford, Australia its Alexander, and its Bragg, and such losses retard further the growth of science in a new country. Rarely, if ever, was the final acclimatisation of science outside Europe achieved until the Government of the country overseas succeeded in inducing a few scientists belonging to some traditional centre, to settle down in their territory and allowed the newcomers to develop there a new home of scientific life moulded by their own standards. This demonstrates perhaps most vividly the fact that science as a whole is based—in the same way as the practice of any single research school—on a local tradition, consisting of a fund of intuitive approaches and emotional values which can only be transmitted from one generation to the other through the medium of personal collaboration.

Scientific research—in short—is an art; it is the art of making certain kinds of discoveries. The scientific profession as a whole has the function of cultivating that art by transmitting and developing the tradition of its practice. The value which we attribute to science—whether its progress be considered good, bad or indifferent from a chosen point of view—does not matter here. Whatever that value may be it still remains true that the tradition of science as an art can be handed on only by those practising the art. There cannot therefore be any question of another authority replacing scientific opinion for the purposes of this function; and any attempt to do so can result only in a clumsy distortion and—if persistently applied—in the more or less complete destruction of the tradition of science.

PROFESSIONAL scientists form a very small minority in the community, perhaps one in ten thousand. The ideas and opinions of so small a group can be of importance only by virtue of the response which they evoke from the general public. This response is indispensable to science, which depends on it for money to pay the costs of research and for recruits to replenish the ranks of the profession. Clearly science can continue to exist on the modern scale only so long as the authority that it claims is accepted by large groups of the public.

Why do people decide to accept science as valid? Can they not see the limitations of scientific demonstrations—in the pre-selected evidence, the pre-conceived theories, the always basically deficient documentation? They may see these shortcomings, or at least they may be made to see them. The fact remains that they must make up their minds about their material surroundings in one way or another. Men must form ideas about the material universe and must achieve definite convictions on the subject. No part of the human race has ever been known to exist without a system of such convictions and it is clear that their elimination must mean intellectual death. Without them man falls to the level of the beast as regards both the state of his mind and the level of his technical achievements. That must remain out of the question. The choice therefore open to the public is only that of believing in science or else in some rival explanation of nature, such as that offered by Aristotle, The Bible, Astrology or Christian Science. Of these alternatives the public of our times has in its majority chosen science; and it is the basis of this choice that concerns us here.

Historically, the origin of the decision is not difficult to trace. There were two main battles, one that opened in the sixteenth century against Aristotelian mechanics and astrology and another that opened in the nineteenth century against the cosmology of the Bible. Both of these led to long-drawn campaigns in which the ideas of science spread rapidly generation by generation, and finally

extended their influence over all the peoples led by the West.

How was this result achieved? It was favoured in the first instance by the whole movement of the Renaissance, which aroused independent judgment among educated people. This awakening weakened the forces opposing the dissemination of science. In these circumstances the convincing power of science proved greater than that of its rival. When Galileo demonstrated that objects of widely different weights, when dropped simultaneously from the tower of Pisa, all reached the ground at the same moment, this proved to every witness of the experiment that Aristotle was wrong in teaching that such bodies fall at different rates proportional to their weights. These practical tests were of the same kind as those used by people engaged in the various crafts of mining, building, and in the arts of war; people willing to think for themselves could not fail to be impressed by them. Though scientific proof was not completely accessible to the layman, what he could be shown proved much more convincing to him than the rival arguments based on Aristotle, the Church Fathers, Astrology or the Bible; and this has continued to hold to this very day.

This does not mean that the victory of science is either complete or final. Pockets of anti-scientific views persist in various forms. Scientific medicine is rejected by that part of the public in Western countries which professes Christian Science. Fundamentalism challenges geology and evolution. Astrology has a more or less vague ascendancy in wide circles. Spiritualism carries on a borderline existence between science and mysticism. These persistent centres of heterodoxy are a constant challenge to science. It is not inconceivable that from one of these there may emerge in the future some element of truth inaccessible to the scientific method, which may form the starting point of a new interpretation of nature. In any case at present these anti-scientific movements constitute an effective check on the popular acceptance of science: the failure of their efforts to spread their doctrines, shows that science remains considerably more convincing than any other of the possible alternatives.

So long as this is the case, science could be discredited with the public only by stopping the channels through which it is disseminated and by suppressing at the same time the desire of people to think for themselves. There may be reasons—which may even conceivably be good ones—for doing these things: but the result could obviously be considered only as a distortion or suppression, not as a re-direction of the appreciation of science by the people.

I HAVE shown that the forces contributing to the growth and dissemination of science operate in three stages. The individual scientists take the initiative in choosing their problems and conducting their investigations; the body of scientists controls each of its members by imposing the standards of science; and finally the people decide in public discussion whether or not to accept science as the true explanation of nature. At each stage a human will operates. But the exercise of will is fully determined on each occasion by the responsibility inherent in the action; and hence any attempt to direct these actions from outside must inevitably distort or destroy their proper meaning.

There are two recent instances on record of attempts made to break the autonomy of scientific life and to subordinate it to State direction. The one made by National Socialist Germany is so crude and cynical that its purely destructive nature is easily demonstrated. Take the following utterances credibly attributed to Himmler, in which he reproves German scholars who refused to accept as genuine a forged document concerning German pre-history:

> We don't care a hoot whether this or something else was the real truth about the pre-history of the German tribes. Science proceeds from hypotheses that change every year or two. So there's no earthly reason why the party should not lay down a particular hypothesis as the starting-point, even if it runs counter to current scientific opinion. The one and only thing that matters to us, and the thing these people are paid for by the State, is to have ideas of history that strengthen our people in their necessary national pride.

Clearly Himmler only pretends here—as a mere form of words—that he wishes to readjust the foundations of science; his actual purpose is to suppress free enquiry in order

to consolidate a particular falsehood which he considers useful. The philosophical difficulties in the position of science are mentioned only in order to confuse the issue and to cloak—however thinly—an act of sheer violence.

THE attempts of the Soviet Government to start a new kind of science are on an altogether different level. They represent a genuine effort to run science for the public good and they provide therefore a proper test of the principles involved in such an attempt.

We will illustrate the process and its results by the example of genetics and plant-breeding, to which governmental direction was applied with particular energy. The intervention of the State in these fields began about the year 1930 and was definitely established by the All Union Conference on the Planning of Genetics and Selection held in Leningrad in 1932. Up to that time genetics had developed and flourished in Russia as a free science, guided by the standards that were recognised in other countries, throughout the scientific world. The Conference of 1932 decided that genetics and plant-breeding should henceforth be conducted with a view to obtaining immediate practical results and on lines conforming to the official doctrine of dialectical materialism, research being directed by the State.

No sooner had these blows been delivered against the authority of science than the inevitable consequences set in. Any person claiming a discovery in genetics and plant-breeding could henceforth appeal directly over the heads of scientists to gullible practitioners or to politically minded officials. Spurious observations and fallacious theories advanced by dilettants, cranks and impostors could now gain currency, unchecked by scientific criticism.

An important case of this kind was that of I. V. Michourin, (1855–1935) a plant-breeding farmer, who some years earlier had announced the discovery of new strains of plants produced by grafting. He claimed to have achieved revolutionary improvements in agriculture, and to have obtained a striking confirmation of dialectical materialism. The opinion of science on the contrary was—and still remains—that Michourin's observations were mere illusions, that they referred to a spurious phenomenon, known by the name of "vegetative hybridisation" which had been frequently described before. The illusion can arise from an incomplete statistical analysis of the results obtained and may be occasionally supported also by the fact that viruses are transmitted to the graft and and its offsprings. The occurrence of true hereditary hybridisation by grafting would be incompatible with the very foundations of modern biological science and its existence had definitely been discredited by the formulation of Mendel's laws and the discoveries of cytogenetics.

The denial of Michourin's claims by scientific opinion now lost its force. His work appealed to the practitioner and it conformed to the philosophy imposed by the State. It thus fulfilled both the criteria which had replaced the standards of science. Hence—inevitably—Michourin's work was now given official recognition. The Government, in its enthusiasm over this first fruit of its new policy in science, went even further and erected a monument of unparalleled splendour to Michourin. It re-named the town of Koslov and called it "Michourinsk" (1932).

The breach thus made in the autonomy of science laid the field of genetics and plant-breeding wide open to further invasion by spurious claims. The leader of this invasion became T. D. Lysenko—a successful worker in agricultural technique—who expanded Michourin's claims into a new theory of heredity which he opposed to Mendelism and cytogenetics. His popular influence caused hundreds of people without proper scientific training, such as farmers and young students of agriculture, to attempt grafting experiments with the aim of producing "vegetative hybrids." Lysenko has himself described proudly how by the labours of this mass movement vegetative hybrids "poured out like the fruits from the horn of abundance." Aided by claims of this kind, Lysenko gained high recognition for himself by the Government. He was appointed a member of the Academy of the U.S.S.R. and made President of the Academy of Agricultural Science of the U.S.S.R. By 1939 his influence had reached the point that he could induce the Commissariat of Agriculture to

prohibit the methods hitherto used in plant-breeding stations and to introduce, compulsorily, new ones that were based on his own doctrine of heredity and that were contrary to accepted scientific opinion. In a publication of the same year he even went so far as to demand the final elimination of his scientific opponents, by the total abolition of genetics in Russia: "In my opinion"—he wrote—"it is quite time to remove Mendelism entirely from University courses and from the theoretical and practical guidance of seed-raising."

However, the Government hesitated to take the decisive step and a conference was called to clarify the situation. The Editors of the Journal "Under the Banner of Marxism" acted as conveners, and the proceedings, together with an extensive editorial commentary, were subsequently published in that Journal. The reports of this Conference form impressive evidence of the rapid and radical destruction of a branch of science caused clearly by the fact that the conduct of research had been placed under the direction of the State. We may note that the government in this case was a particularly progressive one and that it was aiming at solid reasonable benefits for its own people. It is all the more significant that in spite of this, the result of its action was only to plunge the science of genetics into a morass of corruption and confusion.

The Conference, which revealed these conditions to the outside observer was presided over by M. B. Mitin (a person unknown to international science and probably a representative of the Journal), who in his opening speech outlined once again what the practical and theoretical principles were to which science must conform when under the direction of the Soviet State. "We have no gulf between theory and practice, we have no Chinese wall between scientific achievements and practical activity. Every genuine discovery, every genuine scientific achievement is with us translated into practice, enters into the life of hundreds of institutions, attracts the attention of the mass of people by its fruitful results. Soviet biologists, geneticists and selectionists must understand dialectic and historical materialism, and learn to apply the dialectic method to their scientific work. Verbal, formal acceptance of dialectical materialism is not wanted."

Academician N. I. Vavilov, internationally recognised as the most eminent geneticist in Russia (as shown by his recent election as Foreign Member of the Royal Society) put the case for the science of genetics. He surveyed the development of this science from its inception and pointed out that not a single author of repute anywhere outside Russia would either doubt the soundness of cytogenetics, or would be prepared to accept the existence of so-called "vegetative hybrids."

Such appeals however had now become groundless; with the establishment of State supremacy over science, the authority of international scientific opinion had been rendered void. Vavilov was rightly answered by being confronted with his own declaration made at the Planning Conference of 1932 in which he had deprecated the cultivation of science for its own purposes. Yielding at the time perhaps to pressure, or believing it wise to meet popular tendencies half way, little expecting in any case the far reaching consequences to follow from his relinquishment of principles—he had then allowed himself to say: "The divorce of genetics from practical selection, which characterises the research work of the U.S.A., England and other countries, must be resolutely removed from genetics-selection research in the U.S.S.R."

Such principles having now been generally accepted, Vavilov could raise no legitimate objection if the classical experiments to which he referred, and on which his branch of science was based, were laughed to scorn by men like the practical plant breeder V. K. Morozov—who addressed the meeting as follows: "The representatives of formal genetics say that they get good 3:1 ratio results with Drosophila. Their work with this object is very profitable to them, because the affair, as one might say, is irresponsible . . . if the flies die, they are not penalised." In Morozov's opinion a science which in 20 years had produced no important practical results at his plant breeding station, could not possibly be sound.

This view can in fact be considered as a correct conclusion from the criteria of science now officially accepted (though fortunately by no means universally enforced) in the

Soviet Union. If all the evidence drawn from practically unimportant cases is to be disregarded or at least treated lightly, then little proof can remain in support of the theories of genetics. In such circumstances any simple, plausible ideas such as the fallacies advocated by Lysenko must inevitably acquire the greater convincing power and gain the wider support among all non-specialists, whether practitioners or ordinary laymen. This is in fact what the Conference on Genetics demonstrated. Morozov could assure Lysenko that nearly all practical field workers, agronomists and collective farmers had become followers of his doctrine of heredity.

The authority of science having been replaced by that of the State, it was also logical that political arguments should be used against Vavilov's traditional scientific reasoning. Lysenko for example introduced such arguments as follows: "N. I. Vavilov knows that one cannot defend Mendelism before Soviet readers by writing down its foundation, by recounting what it consists of. It has become particularly impossible nowadays when millions of people possess such a mighty theoretical weapon as 'The short Course of the History of the All-Union Communist Party (Bolshevists).' When he grasps Bolshevism, the reader will not be able to give his sympathy to metaphysics, and Mendelism definitely is pure, undisguised metaphysics."

It was logical again that Lysenko and his adherents should invoke Michourin as an authority whose claims had been established by the State; that Lysenko should speak of "that genius of biology I. V. Michourin, recognised by the Party and the Government and by the country . . ." and declare that it is "false and conceited" on the part of a biologist to think that he could add anything to Michourin's teaching.

In such circumstances there seems indeed nothing left to the hard pressed scientists but to attempt a defence in the same terms as used by their opponents. This is what the eminent geneticist Professor N. P. Doubinin apparently decided to do at the Conference on Genetics. His speech in defence of cytogenetics refers freely to Marx, Engels and the "Short Course of the History of the Communist Party." He reverently mentions Michourin, naming him as a classic next to Darwin. But in his view—as he explains—all these high authorities are directly or indirectly supporting Mendelism. "It is quite wrong," he says, "to describe Mendelism by saying that its appearance represents a product of the imperialist development of capitalist society. Of course after its appearance Mendelism was perverted by bourgeois scientists. We know well the fact that all science is class science."

Such is the last stage in the collapse of science. Attackers and defenders are using the same spurious and often fanciful arguments, to enlist for their own side the support of untutored practitioners and of equally untutored politicians.

But the position of the defenders is hopeless. Science cannot be saved on grounds which contradict its own basic principles. The ambitious and unscrupulous figures who rise to power on the tide of a movement against science, do not withdraw when scientists make their last abject surrender. On the contrary they stay to complete their triumph by directing against their yielding opponents the charge of insincerity. Thus Lysenko says, "The Mendelian geneticists keep silent about their own radical disagreement with the theory of development, with the teaching of Michourin," and even more jeeringly is the same taunt made by Lysenko's assistant Professor I. I. Prezent: "It is new to find that all of them, some more sincerely than others, all of them try to give the impression that with Michourin at least they have no quarrel."

Such taunts are unanswerable and their implications are shattering. They make it clear that scientists must never hope to save their scientific pursuits by creeping under the cloak of essentially anti-scientific principles. "Verbal, formal acceptance of these principles"—the Chairman had sternly warned from the beginning—"is not wanted."

THE demonstration given here of the corruption of a branch of science caused by placing its pursuit under the direction of the State, is, I think, complete. The more so—I wish to repeat—as there is no doubt at all

the unwavering desire of the Soviet Government to advance the progress of science. It has spent large sums on laboratories, on equipment, and on personnel. Yet these subsidies, we have seen, benefited science only so long as they flowed into channels controlled by independent scientific opinion whereas as soon as their allocation was accompanied by attempts at establishing governmental direction they exercised a violently destructive influence.

We may hope and expect that one day the Soviet Government will recognize the error in such attempts. That they will realize, for example, that their plant-breeding stations are operating on lines which were abandoned as fallacious in the rest of the world about forty years earlier.

What can a government do when it realizes such a state of affairs? What course can it then take to restore the functions of science?

According to our analysis the answer cannot be in doubt. One thing only is necessary—but that is truly indispensable. It is only necessary to restore the independence of scientific opinion. To restore fully its powers to maintain scientific standards in respect of all their proper functions, in the selection of papers for publication, in the selection of candidates for scientific posts, in the granting of scientific distinctions and in the award of special research subsidies. To restore to scientific opinion the power to control by its influence the publication of textbooks and popularizations of science as well as the teaching of science in universities and schools. To restore to it above all the power to protect that most precious foothold of originality, that landing ground of all new ideas, the position of the independent scientist—who must again become sole master of his own research work.

There is still time to revive the great scientific tradition of Russia which, although at present distorted in many respects, is very far from being dead. The recent great progress of Russian mathematics, and of many other fields in which State control has never been effectively applied, proves that the valuation of science for its own sake still lives in U.S.S.R. Let scientists be free once more to expound their true ideals. Let them be allowed to appeal to the Soviet peoples; to ask for their support of science on its own grounds, for the understanding and love of science when pursuing its own immortal purpose. Let them be free to expose the cranks and careerists who have infiltrated into their ranks since the inception of "planning" in 1932. Let the Soviet scientists become affiliated again to the body of international science.

The very moment that scientists regain these freedoms, science will flourish again. Overnight it will rise again free of all the confusion and corruption which is now affecting it; and, aided by the rich endowments which it is receiving from the State, the Russian scientific genius will once more speed on, unhampered, to new great achievements.

However, the current of future events may well tend towards the very opposite course. We are experiencing to-day a weakening of the principles of scientific autonomy in countries where science is still free. There is a movement afoot among scientists themselves, urging that science should be adjusted to social ends. "Science must be marshalled for the people" Professor H. Levy is reported to have proclaimed at a popular rally of scientists in London only a few weeks ago. Fired by misguided generosity these scientists would sacrifice science—forgetting that it is theirs only on trust for the purpose of cultivation, not theirs to give away and allow to perish.

Our analysis seems to leave no doubt, that if this kind of movement prevailed and developed further: if attempts to suppress the autonomy of science, such as have been made in Russia since 1932, became world wide and were persisted in for a time, the result could only be a total destruction of science and of scientific life. Single individuals could perhaps continue to study pure science and to achieve sporadic progress as some did even during the Middle Ages. But the swift and steady progress of discovery, as experienced in the past 100 years, would be brought to a standstill and presently the main body of science itself would disintegrate and fall into oblivion.

That is why we must recognize the essentially autonomous nature of science with all its great implications.

THE NATIONAL PEST CONTROL ASSOCIATION*

By J. J. DAVIS

INSECTS appeared millions of years ago, and insect remains that have been preserved as fossils through the ages give us a fair idea of the early forms of insect life and their possible economic significance. Perhaps the first references in literature to the economic significance of insects are those recorded in the Old Testament of the Bible, where we read of the ravages of such insects as flies, locusts (grasshoppers), cankerworms, and palmer worms. Doubtless insects have been a problem of man since his earliest existence.

Entomology, the science of insect life, is a relatively recent science, and economic, or applied, entomology, as a science, is even more recent. In fact we may say that the science of economic entomology dates back not more than seventy-five years. Prior to 1870 entomologists were chiefly interested in the collection and identification of insects. With the advent of the cotton caterpillar and the Colorado potato beetle in the seventies the economic significance of insects became increasingly important, and with the introduction and establishment of insects into North America from foreign countries the insect problems became doubly important. During these past seventy-five years of progress in economic entomology emphasis has been given to the problems of controlling insects destructive to animals and plants that provide food and clothing and to insects and other arthropods that are responsible for the carrying and spread of diseases of humans and domestic animals and plants.

In years past those interested in entomology have been able to elect it as a vocation in the fields of teaching, research, extension, and regulatory work—largely in federal or state agencies. More recently, manufacturing industries, especially the chemical industries, have demanded increasingly large numbers of entomologically trained men. At the same time some college trained persons and some who developed from apprenticeships foresaw opportunities in the field of insect and rodent control as consultants and as service operators. These service operators, who practiced insect and rat control largely in hotels, warehouses, and homes as much as seventy-five years ago, became known as "exterminators," and even today are so called in many localities. Methods in the early days were crude and tedious, but records indicate successful operations.

A national emergency some twelve years ago served to bring together a nucleus of persons and firms engaged in structural pest control work. To be sure, prior to that time, there had been local organizations of exterminators in several cities, and local city ordinances had been enacted to curb reckless fumigation practices. However, the necessity under NRA requirements for preparing a national industry code must be emphasized as the occasion for the birth of a recognizable pest control service industry. It is to the credit of the comparatively few assembled exterminators, now known as pest control operators, or PCO's, that the possibilities and the needs were recognized for the formation of a permanent organization. Thus, the National Association of Exterminators and Fumigators was formally organized. The change in 1936 to the present name, National Pest Control Association, was more than a mere change of wording; it was evidence of an already broadened outlook. The organizers foresaw the need and demand for pest control service as a profession of great importance to humanity and the necessity for a co-operating industry to meet this need.

Today the National Pest Control Association is a well-organized group of 685 pest control establishments, representing an estimated personnel of 5,800 individuals. Aside from the annual meetings, dealing largely with industry problems, the Association is co-operating in maintaining five regional educational conferences, conducted annually at Purdue University, University of California, Louisiana State University, Massa-

* This is the first of a series of articles that are to be published from time to time in THE SCIENTIFIC MONTHLY on semiprofessional and trade associations whose effectiveness is partly dependent on the progress of science.—Ed.

chusetts State College, and the University of Montreal. Thus, through the union of the pest control industry with science the goal of a pest control profession is being achieved.

Through the annual meetings of the N.P.C.A. and the regional conferences the pest control operators have developed standards and ethics accepted by all members of the Association. The code of ethics includes:

1. *Relation of Member to Public:* The member in his advertisements or other solicitations of business should not use tricky, fraudulent, or misleading wording or methods.

2. *Relation of Member to Client:* The member shall thoroughly analyze the requirements of his clients and shall conscientiously recommend the means best suited for the client's needs.

3. *Professional Services:* The member upon accepting a contract or service agreement shall render skilled, intelligent, and conscientious service.

4. *Relation of Member to Competitor:* The member shall not publicly criticize the business or private affairs of a competitor.

5. *Relation of Member to Association:* The member shall be loyal to the principles of his Association and active in its advancement.

Standards carefully prepared and adopted by the Association or well along in preparation are concerned with fumigation, termite control, and control of rodents, ants, and roaches. These standards involve a knowledge of entomology as it relates to identification, life cycles, and habits of pests; a knowledge of the chemistry and toxicology of insecticides; and an understanding of the principles of construction and of sanitation. They likewise involve procedures of treatment, with special reference to safety practices. Experience has taught the pest control operator who follows these official standards that there are no substitutes for accurate analysis, sound technique, and skillful application.

Entomology is now recognized as one of the important sciences. It has a direct and close relation to profitable agriculture and to the health and well-being of all peoples. In North America three major organizations represent this important science:

1. The American Association of Economic Entomologists, organized in 1889 to represent research on insect control.

2. The Entomological Society of America, organized in 1907 to represent the "pure" science of entomology.

3. The National Pest Control Association, organized in 1933 to represent the commercial service phase of applied, or economic, entomology as it is related to structural pest control.

This last organization has recognized its dependence upon the other two for research, and as a result the industry is rapidly improving in its methods, standards, and ethics through the development and distribution of the knowledge gained from this research, both current and planned.

Thus we find that the pest control operators are rendering valuable public services, which will doubtless gain in importance and significance in postwar days. Their job is to control pests of many kinds: those that menace health, as houseflies, mosquitoes, body lice, and fleas; those that destroy property, as clothes moths, carpet beetles, silverfish, termites, powder post beetles, rats, mice, and rot fungi; and those that are annoying, as ants, roaches, bedbugs, and book lice. Consequently, it is necessary for the PCO to know how to identify these various pests, what to prescribe (based on his knowledge of the life history and habits of each pest), and the best methods of applying the remedy, to the end that the undesirable condition will be eliminated.

SCIENCE ON THE MARCH

AN INDIAN RELICT AREA

THERE is a detailed map of Southbridge, Massachusetts, dated 1830, republished by the Quinnebaug Historical Society in the Ammidown Historical Collections. Depicted on this map in the southwestern portion of the township, extending south across the state line into Connecticut, is an area labeled "Woods." Inasmuch as this spot was the last bit of original land in that section untouched by white men, an elucidation of the ecology of the area is worthy of more than passing mention.

This was the site of the Hatchet Lake Indian Reservation, the last primeval land, in an encompassing farming area, to be controlled by the Indians—the last stand of Indian influence that had once been felt throughout southern New England.

Twenty-five years ago I had the privilege of discussing this area with the late Dr. Carey C. Bradford, then Medical Examiner of Southbridge, and his brother Henry, descendants of the famous early Governor Bradford of Massachusetts. Many generations of Bradfords had made Woodstock, Connecticut, their home. These conversations revealed much that later proved of great assistance in fitting together scattered puzzling pieces of information into a full realization of the type of country which this relict represented in 1830, now so greatly changed.

At the time of Indian occupancy the vegetation of this section was characterized by an open forest of oak,[1] chestnut, and hickory on the slopes; white pine and hemlock in the swamps; and bushy plains and blueberry barrens on the overly drained acid-soil plateaus and hilltops.

In other words, the uplands were essentially a subclimax maintained by the conflagrations set by the Indians during dry periods of fall, winter, and early spring to preserve the openness of the country, to facilitate travel and hunting, and to maintain an adequate food supply both for themselves and for the great abundance of game birds and mammals that this type of country was capable of supporting. In fact, the whole ecology of the Indian-occupied country was primarily a symbiotic relationship among the plant associations, the Indian, and his game animals.

The Indians' fires favored the tough nut- and acorn-bearing timber at the expense of the fire-susceptible white pine, hemlock, birch, maple, and other trees of the natural climax, which on the whole were valueless for food in the Indian economy. The fires also preserved, as well, the blueberry barrens,[2] which if left unburned would soon grow up to brush. The blueberry heaths in turn furnished food for the Indians as well as for the countless game. They were the habitat of the heath hen, now extinct. They were important feeding grounds for the millions of passenger pigeons, exterminated during the last part of the nineteenth century. The last wild turkey in Connecticut was killed in this section about 1845. The Virginia, or white-tailed, deer was killed out before 1820 but returned later under the protection of stringent game laws to inhabit the increasing brush lands.

According to Mr. George Abbott of the Southbridge Water Company, the present owners of this area, the Indians died out or moved away, and the Reservation was abandoned about 1831.

Upon cessation of the Indians' fires, the upland woods and grassy plains soon grew up to brush, which developed rapidly into the white pine and gray birch stands so characteristic of this area in the eighties and

[1] The scientific names of the plants mentioned in this article are as follows: "oak," principally *Quercus velutina* Lam., *Q. alba* L., *Q. borealis* Michx., and *Q. coccinea* Muenchh.; "chestnut," *Castanea dentata* Borkh.; "hickory," *Carya ovata* K. Koch and *C. glabra* Sweet; "white pine," *Pinus strobus* L.; "hemlock," *Tsuga canadensis* Carr.; "bushy plains," low scattered growths of *Quercus ilicifolia* Wangh.; "blueberry barrens," largely *Vaccinium pennsylvanicum* Lam. and *V. vacillans* Kalm; "Indian grass," *Andropogon scoparius* Mich.; "birch," *Betula populifolia* Ait. and *B. lenta* L.; "aspen," *Populus grandidentata* Michx. and *P. tremuloides* Michx.; "red maple," *Acer rubrum* L.; "mountain-laurel," *Kalmia latifolia* L.

[2] The present commercial blueberry barrens of eastern Maine have to be burned over every other year to insure maintenance of growth and yield.

nineties. The dense character of the brush slowly but surely choked out the low blueberry growths and Indian grass.

Other sections of the Reservation, particularly those on Hatchet Hill, were cleared by the whites for sheep pastures. Dr. Bradford told of his father witnessing this transition, which resulted in the extermination of the rattlesnake, until then abundant on Hatchet Hill. The trees were cut down in June and allowed to dry out until late summer; then fires were started around the entire periphery of the lot. Soon burning fiercely, the fire consumed the dried leaves and branches together with the rattlesnakes, which, attracted by the cover and food supply, had left the ledges and congregated in the tangle.

The sound green logs, which were only superficially scorched, were dragged out by oxen and utilized for timber. Sheep were then turned lose to pasturage.

Sometime after the Civil War the pastures failed and were abandoned. In places they grew up to white pine. The pine groves, after having been cut for lumber and box wood fifty or sixty years later, were succeeded by deciduous trees: principally birch, aspen, and red maple. Thick growths of oak sprouts developed in the former timberlands.

The original oak and chestnut woodlands composed of trees several centuries of age, which had been a vast food reservoir for Indian and game alike, were lumbered out during the last quarter of the century.

According to a local newspaper clipping, dated 1931, which I have in my possession, these woods were cut off about 1881 "by the late Daniel Whitford according to the dwellers in that neighborhood. At that time it was a virgin forest of oak and chestnut. Not far from the spot there had previously been set up the first portable sawmill ever put in operation in this part of the state. An older lumberman named Googins, from Bellingham, came here, set up the mill and soon converted the big trees into thousands of feet of lumber."

The entire area today is one of thick brush and dense young woodland; a barren wilderness incapable of supporting wild turkey, pigeon, heath hen, or Indian populations, even if such still existed. A notable feature of this area in its present condition is the abundance of mountain-laurel. In some places there are many acres of this shrub to the exclusion of most other types of vegetation. This type of country supports the following characteristic game animals and birds: the varying hare, or snowshoe rabbit; the Virginia deer; the ruffed grouse; and the woodcock.

A final word about the Indians: Bowen (1926) in his History of Woodstock, Connecticut, volume 1, p. 537, stated that the Wabbaquassetts "who lived in the Hatchet Pond Reservation gradually disappeared. Rum and cider caused their degeneration." Although this may be true in part, I doubt that it was the whole story by any means. It is more reasonable to suppose that the Indians were starved out by the activities of the whites in exterminating the game birds and mammals that were so vital to the Indians' mode of existence. Weakened by improper diet, the remainder fell easy prey to smallpox and measles.—S. W. BROMLEY, Bartlett Tree Research Laboratories, Stamford, Conn.

RESEARCH IN THE ANTARCTIC

WHALE oil not only makes glycerin for explosives, it also makes margarine. Small wonder then that today it has become one of the world's most important commodities.

Before the war the business of whaling was mostly carried out by Norwegians, but by far the greater part of the whale oil taken last year was secured by Britain. The most fruitful whaling grounds are in the Antarctic Ocean, where the whales are bigger, fatter, and more plentiful than anywhere else. To make the work of the whaling expeditions safer and more productive, much research has been necessary on the meteorology of the Antarctic Ocean, on the habits and migratory movements of whales, and on the general economic resources of the Antarctic.

This work is mostly undertaken by a British organization—the Discovery Committee—which acts under the authority of the Secretary of State for the Colonies. The Committee, which has been at work since 1925, is also charged with investigations on general oceanography, ice conditions, seals, fish, and other aspects of the fauna and flora

of the Antarctic Ocean, and with sounding and coastal surveying. But research is mainly focussed on the natural history of whales.

During the years before the war the Committee's work was carried out by three ships: the Royal Research Ship *Discovery* (736 tons), the R.R.S. *Discovery II* (1036 tons), and the R.R.S. *William Scoresby* (324 tons). A Marine Station was established at South Georgia near one of the shore-based whaling stations, and detached parties worked in factory ships and other stations.

The more direct investigations on whales have included the anatomical examination of many thousands of whales at whaling stations and in factory ships, principally for studying their breeding and growth; the marking by numbered darts of some thousands of living whales (mainly by the *William Scoresby*) for investigation of migrations and distribution; and observations at sea on their distribution and habits during the voyages of all three ships. In addition, some extensive collections of ovaries have been acquired by the courtesy of the whaling companies, for these organs, which retain traces of previous pregnancies, give a clue to the age of the whale.

It would be impossible to give in a few lines even the barest summary of the results of these investigations, but it may be said that the great whalebone whales breed slowly but grow up comparatively quickly, that they spend the summer in the Antarctic where food is abundant, and migrate to the same part of the Antarctic in the following summer. Of the three important species the medium-sized finback whales (*Balaenoptera physalus*), averaging about 66 feet long, are still plentiful in the Antarctic Ocean, but the stocks of great blue whales (*B. musculus*), averaging about 75 feet long, and smaller humpback whales (*Megaptera nodosa*), averaging about 54 feet long, were reduced as a result of hunting before the war.

The more comprehensive research was carried out during one commission of the *Discovery* and five subsequent commissions of the *Discovery II*, with the co-operation from time to time of the *William Scoresby*. This amounted in effect to a hydrological and biological survey of the whole Antarctic Ocean, though the observations were more concentrated in the Falkland Sector than elsewhere, and a period in nearly every commission was devoted to coastal surveys and to what might be termed scientific exploration in the Falkland Islands Dependencies. The *Discovery II* is a specially efficient ship, with a maximum cruising range of 10,000 miles and equipment for almost all forms of oceanographical research.

The Antarctic Ocean has been covered with a network of voyages, including two circumpolar cruises, the ship stopping periodically "on station" to take a series of water samples and temperatures at all depths from surface to bottom and to fish a variety of nets. Frequent echo soundings and meteorological observations were made, and continuous records were kept of whales, birds, icebergs, etc. Many such voyages ran north and south between subtropical regions and pack-ice, others were concentrated in the belt north of the ice, which forms the summer habitat of whales, and sometimes the same tracks were followed at different times of year for the study of seasonal variations. Specially intensive observations were made on the whaling grounds of South Georgia and the South Shetland Islands.

Observations have been made at all times of year, though rather less in the winter than in the summer months. Severe weather conditions are met with almost everywhere. With the *Discovery II*, however, it has been found possible to make a full series of observations in a moderate gale. In stronger winds at least the deeper hauls with water-sampling instruments and nets must be omitted, for the pitching of the ship may cause the wires to break, with the loss of valuable apparatus.

When a research ship is constantly at work on such a variety of subjects, the scientific data and collections accumulate much faster than they can be analyzed and reported upon unless a very large staff is employed at home. The Discovery Committee's work at sea was suspended when war broke out, and not much could be done on the accumulated material in wartime. Thus the work cannot be completed until some years after the war.

However, much has already been done.

The principal water masses and water movements of the Antarctic Ocean and the seasonal advance and retreat of the pack-ice have been mapped out, and much is already known of the chain of nourishment that begins with the nutrient salts in the water upon which depend the minute vegetable organisms so abundant in the surface waters of the Antarctic. These organisms (mainly the diatoms) form the pastures of the ocean and feed the shoals of small crustaceans, which in turn are the staple food of whales and of many fish, seals, and birds. These crustaceans, are confined to waters south of the Antarctic convergence (the line which marks the northern boundary of the cold Antarctic surface water), and their distribution, which nearly corresponds with the maximum area covered by the pack-ice, is closely connected with the summer distribution of the whales.

Many parts of the Falkland Islands Dependencies have been surveyed and much information acquired on the physiography, geology, and biology of these lands.

In the course of the work very extensive collections of the marine fauna and flora have been made and reported upon by specialists, and several minor problems have been investigated. Apart from the general program of oceanographical research, the *William Scoresby* has undertaken a trawling survey of the shallow waters between the Falkland Islands and the Patagonian coast, and a survey of the Peru coastal current.

Two scientific results of the work are published by the Committee in a series of memoirs entitled the "Discovery Reports" (Cambridge Press), of which twenty-two volumes have so far been issued. For the most part these are technical papers, but from time to time semipopular accounts of the work of the ships have been given to the Royal Geographical Society and published in the *Geographical Journal.*

Most of the Committee's staff are now occupied in various forms of national service. Work in Britain has been continued, however, by a small nucleus of the staff, and some further reports have been issued since the war began. And this year, despite the war, scientific research and survey work were resumed in some of the most remote of British Dependencies, the Falkland Islands. Scientific and administrative personnel arrived there in April, established well-equipped bases, and settled down to work in the Antarctic, prepared to remain there for a considerable period.—N. A. MACKINTOSH, Director of Research to the "Discovery Committee" in Britain.

BOOK REVIEWS

COSTS OF DENTAL CARE

Costs of Dental Care for Adults under Specific Clinical Conditions. Dorothy Fahs Beck assisted by Mary Frost Jessup. 307 pp. Illus. 2nd ed. 1943. American College of Dentists.

DESPITE the title of this book, it is not merely a compilation of statistical data. Under the auspices of the Socio-Economics Committee of the American College of Dentists and as a doctoral thesis, the author reviewed the social setting of health services and time and cost studies, made a detailed survey of the time and cost of dental care for a special group, and summarized her findings and their implications. It is interesting to note that the delay between completion of the work (Dec. 1941) and approval for publication (Jan. 1943) has not dulled the import of even the review portion, and that the major changes which would have rendered the study obsolete, "application of scientific advances that would reduce greatly the incidence of dental caries or alter substantially current methods of practice," have not come to pass. Compulsory health insurance was considered seriously by legislators even before 1920. Many suggested plans include dental care, yet acceptable statistics on cost of dental maintenance care for adults have been, at best, shrewd guesses and those for cost of initial care usually estimates based on disease prevalence data.

The present material was secured from study of the records of 485 clients of Dental Health Service, Inc., of New York City. These individuals were adults, had attended the nonprofit clinic for 4 or 5 out of 5 consecutive years, and had followed the advice of the staff to secure adequate dental care. The qualified group (selected from 21,681 patients served) included 67% females, represented a younger group than a cross section of the population, and was heavy on low-income professional and clerical workers. However, its needs approximated that of the general population and its D.M.F. (an index of the tooth destruction from disease) was comparable with available figures. At the clinic the cost of initial care averaged \$52.66 per person and would have cost \$68.34 at low, urban private fees. Average maintenance cost was \$10.05 per person per year at clinic fees (\$12.62 at low, urban private fees). The initial care took 8.5 hours of chair time, with 2.4 hours per year to maintain dental health. In general, older individuals required more initial care. Details and comparisons are given both in profuse thesis style and in more palatable forms. The author of this study pointed out that it emphasized the oral health values of medical care, economy of regular dental care, the future of the population to secure adequate maintenance care, factors affecting dental needs (age, economic status, etc.), and the need for adjustment of fee policies. For instance, it was found that, on the basis of usual fee scales, dentists reduce their own hourly earnings by encouraging oral health because the procedures used on maintenance care are relatively too low in fee range compared with replacement (denture) fees. The implications in regard to dental personnel involve astronomical calculations which lead to the conclusion that if all the dentists in the United States in 1938 had devoted themselves exclusively to initial care, they would have completed dental care for only 20,000,000 adults (be sure to correct the typographical error of 2,000,000 on p. 253 of your copy). With the number of graduating dentists decreasing annually (except for the A.S.T.P. spurt) and even without considering that a huge percentage of dentists are now in the armed services, the futility of a nation-wide compulsory dental health program is evident. The costs for initial care of our 27 million "dentally indigent adults" would be over a billion dollars and their maintenance costs over 300 million dollars per year.

The solution of the problem obviously is not just compulsory dental health insurance and free care for the "dentally indigent," but lies primarily in prevention or control. This reviewer cannot be so gloomy about prospects of caries control as is the author. The author discusses economical ways of providing care, limitation of services, methods of payment, and combination of methods. The fact must remain, from the viewpoint of the oral pathologist, that the dental care

problem is one which requires solving a problem of disease or diseases. The socioeconomist will not eliminate the need for care but may do an excellent job in suggesting methods of caring for dental diseases while science plods slowly toward its goal of discovering causes and preventives. Although there is much laborious statistical material in this volume, its reading is recommended for dental practitioners who are aware of their social responsibilities and desire to do something about those responsibilities, and for those for whom the report is designed: (1) leaders of the health professions and of the public who will develop health plans; (2) those of the rank and file who must evaluate these plans and, (3) private practitioners who need to interpret the value of maintenance care to their patients. Few should plan a cover-to-cover trip and none an evening of light entertainment.—Hamilton B. G. Robinson.

ELECTRONICS FOR LAYMEN

Electronics: Today and Tomorrow. John Mills. 178 pp. 1944. $2.25. D. Van Nostrand Co., New York.

Prof. J. B. S. Haldane once remarked that "the ordinary man must know something about various branches of science, for the same reason that the astronomer, even if his eyes are fixed on higher things, must know about boots. The reason is that these matters affect his daily life." One will readily agree that he has sufficient reason for knowing something about science, but the average man's anomalous attitude toward science is a thing to marvel at. He is willing to tolerate the scientist as an ivory-towered "screw-ball" or a "high-brow" professor; he even consents to his helping win the war; at pure science he simply shakes his head. But let the man of science produce one of the wonder gadgets that affect his daily life (usually the by-product of many years of research and laboratory drudgery) and the average man accepts it, with a sublime pragmatic faith, and murmurs—

> I know not how my radio
> Gathers its waves from air;
> Indeed, not only don't I know,
> But neither do I care.

Mr. Mills has written this book on electronics for the "intelligent layman" in another effort to penetrate his indifference and to satisfy his real or imagined curiosity. The author believes that there may possibly be a number of such laymen who may want to know just how an electric eye works, how roadside signals are produced on the panels inside the cabs of locomotives, what frequency modulation is all about, how artificial fever is produced, how television really works, what electron microscopes are good for, or even the answer to so simple (?) a question as: What is an electron? These matters represent the marvels in electronics that we have all accepted and are beginning to take for granted, and there are many more on the way. Because of the war some of them cannot now be publicly divulged. "Electronic devices," says Mr. Mills, "are today of vital importance in every form and theatre of warfare; and their peacetime applications, following the war, promise to exceed those that preceded in variety and in social and economic consequences." As an example, consider a B-29 superfortress, which is said to have enough electronic equipment aboard to astonish the electrical engineers themselves.

In simple and in as nontechnical language as practicable Mr. Mills proceeds to expound the science of electronics, pure and applied. Following an introductory chapter on the nature of electrons in general, his discussion resolves into two parts: (1) Electron Tubes, and (2) Electronic Devices. Under the first heading he discusses hot cathodes, diodes and rectifiers, De Forest's audion, the vacuum tube, tetrodes and pentodes, oscillators, electricity from light, and gas-filled tubes. Among the electronic devices described are electron guns and television, electron optics and photography, ultrahigh-frequency generators, and cyclotrons. Radar is not included.

Whether the author has succeeded in his job of popularization will, naturally, depend on the reader and on how deep his desire is to understand. Even in their simplified form electronics are not too easy going, and even an intelligent layman reading the book, unless he has been grounded in more modern physics than I think he has, will find himself suddenly waking up and wondering where

he is. The value of the book is not that it makes all the principles and details of electronics crystal-clear to the most opaque intelligence, which of course it doesn't, but rather that *in toto* it leaves the reader with a good feeling that he is at least on the way to understanding. He feels that although his increase of knowledge may not be quantitatively great—scarcely enough perhaps to enable him (quoting from the jacket) "to discuss a cathode ray tube on the 5:19 for Squeedunk"—it is great in its implications, in opening to him new vistas of knowledge, in giving him a new appreciation and concern for some of the modern miracles of science. Speaking for one layman, I do not pretend to follow everything that Mr. Mills has so patiently expounded, but I have benefited from reading his book and think he has done a most praiseworthy piece of writing. There is the danger, however, that it will find its greatest audience among the *au courant* in electronics, rather than among that teeming multitude of "intelligent laymen," who have often impressed me as being somewhat like the horse that ran smack into the side of a barn. "He ain't blind," said the indignant owner. "He just don't give a damn."—PAUL H. OEHSER.

HEAT VS. HUMIDITY

Climate and the Energy of Nations. S. F. Markham. 236 pp. Illus. 1944. $3.50. Oxford University Press.

Major Markham informs the reader that he has set out in this book to determine "whether or not climate and climate controls influence civilization," but the reader will not find a great deal of evidence presented in behalf of the negative side. Hence the book is pretty much an argument after the fact, and such an important influence on the decline of civilizations as the exhaustion of natural resources is somewhat brusquely treated. Declaring flatly that "of all the factors that may assist or retard the development of a nation the most permanent . . . is climate," the author proceeds to analyze the optimum climatic conditions for man and then to examine civilizations of the past and present to see how they conform. As might be expected from such a method, he finds a high correlation. This is hardly an original discovery, and the theory that climate is the prime mover of civilization had been advanced by others, including Ellsworth Huntington in this country. All this the author freely acknowledges.

What makes the book interesting reading, however, is the idea that it is time we did something about the weather. Major Markham sees in air conditioning, which he prefers to consider as a type of "climate control," the most important development of modern civilization. From his final pages, which are somewhat rhetorical, one must conclude that his vision of the future is one in which the nations of the world, united in common zeal for spiritual and material progress under the benign influence of air conditioning, will become centers of enlightenment:

> In short, whilst optimum climatic conditions and controls produce men of the greatest energy, the final direction of that energy, be it for good or ill, is determined by inner thoughts, fears or hopes expressed through the ballot box or bullet, through treaty or terror, according to the spiritual values of the age. Is it too much to hope that, when all men can enjoy the serenity of ideal indoor conditions, the thirst for mortal power will give place to the thirst for mental poise, and to the lust for light?

This reviewer is afraid so; the weather, as any theologian will tell us, cannot be considered the prime cause of human depravity, and the sumptuous "climate control" of Berchtesgaden does not seem to have improved the temper of its occupants.—JOEL W. HEDGPETH.

BEEBE'S NATURALISTS

The Book of Naturalists. Edited by William Beebe. 499 pp. 1944. $3.50. A. A. Knopf, New York.

It is always with a thrill of pleasurable prelibation that we look over a new book by Dr. Beebe, nor have we been disappointed in the present volume of nearly five hundred pages. Dr. Beebe has just returned from another of his famous expeditions, bringing with him this time, not objects from nature, but the naturalists themselves who have written of them. His book consists of selections from the records of representative naturalists, beginning with an Unknown Cave Man of Europe, who painted on cave walls about 25,041 B.C., and ending with Rachel L. Carson who wrote in a book in A.D. 1941.

The book is no mere assemblage of well-

known and hackneyed quotations from the "standard writers," but a collection of new, fresh, fascinating accounts of all sorts and conditions of creatures, some by the old familiar naturalists and some by later less familiar ones. Dr. Beebe, acting as a sort of toastmaster-through-the-ages, has in his book called upon forty-five naturalists of his own selection to tell us a good natural history story, and they have all responded. As examples: Aristotle tells us of fishing-frogs, cuckoos, and other things; The Abbott Thoebaldus of Monte Cassino tells us of whales; Gilbert White tells us of birds, bats, and a tortoise; Thoreau tells of a certain pond; Agassiz, of an expedition; Digby, of mammoths in the flesh; Heard, of half-men; Chapman, of the big Almedo tree; Peattie, of seeds and their sleep; Klingel defends the octopuses; and Carson brings up the rear with an excellent account of the odyssey of the eel. To all these bits of fine writing Dr. Beebe has added two introductory surveys of his own, as well as short biographical notices of each author, thereby taking his place in the book, as is most justly due, in the long assemblage of notable naturalists. The result is not only a book full of delightful nature reading, but a book full of the record of the development of man's knowledge of nature throughout the ages.

Dr. William Beebe, well-known naturalist, explorer, leader of expeditions, writer, and lecturer, holds honorary degrees from several colleges, and is also Elliott, and John Burroughs medalist. He has been Curator of Birds of the New York Zoological Park, and is now the Director of the Department of Tropical Research of the New York Zoological Society and the founder of that Society's Zoological Station of British Guiana. His expeditions have taken him to Mexico, China, India, Borneo, the East Indies, the Sargasso Sea, the Galapagos Islands, and to the depths of the ocean in his celebrated bathysphere. His current investigations are being carried on, not in the ocean, but in the jungles of Venezuela. He is the author of a multitude of scientific papers and monographs, and of twenty books.—LEON AUGUSTUS HAUSMAN.

OURSELVES UNBORN

Ourselves Unborn. George W. Corner. 188 pp. Illus. 1944. $3.00. Yale University Press, New Haven, Conn.

THERE is at the present time an urgent pressure to state scientific facts and deductions in a language comprehensible to the layman. Dr. Corner gives us a vigorous résumé of modern embryology and its significance. He states that the book does not presume any biological knowledge on the part of the reader. This reviewer believes that steady readers of THE SCIENTIFIC MONTHLY could understand it, medical students would see more in it (most textbooks of embryology shoot over their heads), but the layman would "come out by the same door wherein he went." The book is highly recommended to the intelligent public.

Since this is one of the Dwight Harrington Terry lecture series at Yale University, it is concerned with the place of embryological concepts in organized religion. Here the author follows the injunction, "Seek and ye shall find." Illuminating examples illustrate some modern medico-religious institutional practices very little beyond the early middle ages. It is too much to hope that this book will in any way influence them.

The data of human development are accurately and briefly sketched as a background to two main arguments. The first assesses the value of embryology in supporting theories of human descent. The second analyzes the cause of normal succession of embryonic events and of abnormal deviations. The arguments are developed historically and culminate in observations made at first hand by the author. The great support given to genetic factors as causes of early death and malformation is in line with recent medical genetics. Passage of materials across the placental barrier in relation to the age of the placenta needs much study. Here it is briefly discussed.

The vast collections of the Department of Embryology of the Carnegie Institution are drawn upon freely, and the illustrations are of corresponding excellence. The book has a good bibliography and an index.—JOHN G. SINCLAIR.

COMMENTS AND CRITICISMS

The Golden Eggs

The excellent article by Dr. Paul D. Lamson on biotrepy in THE SCIENTIFIC MONTHLY, September 1944, presents a very convincing example for the fact that in contrast to Shakespeare's much quoted sceptical answer to the question "What's in a name," there may be very much in a name. In the case of "biotrepy," there may be in the new name the beginning of a new medico-scientific orientation.

It was partly the confusion of names and concepts which caused Dr. Lamson to coin a new name for the new approach, suggested by him, to the problem of the reactions of the human body to drugs. It is, therefore, this very common confusion which he pictures in calling pharmacology "an old synonym for pharmacy" and in stating that pharmacology "after all is pharmacy, even in name" and that "giving pharmacy the name 'pharmacology' did not change matters."

As I learned in a private communication from Dr. Lamson, he based his statements on an article by Dr. Abel setting forth that "the vague and often erroneous use of the word pharmacology seen in earlier writings, as in the definition . . . of Samuel Johnson (1755), 'an equivalent of pharmacy or pharmaceutics,' is still frequently met with in our time."

Since Abel very definitely and rightly calls the synonymous use of the words (and concepts) pharmacy and pharmacology "erroneous," the scientific world as represented by the readers of this journal has a right to ask for the correct definition of the term pharmacology and of the part of pharmacy and medicine in the development concerned.

The old discipline called "materia medica" scarcely requires a definition. It comprehended all knowledge on drugs and their therapeutical use until the beginning of modern science, and its classic for more than 1500 years was Dioscorides' *De Materia Medica* written in the first century A.D. As long as Galen's classification of drugs in connection with his special brand of humoral pathology dominated official therapy, there was no need for another approach to the problem of the selection and the therapeutical use of drugs.

It was at the end of the seventeenth century that the development of iatrochemistry on the one hand and the new era of physiological investigation on the other had resulted in such an obvious change of therapeutical approach that it found recognition in the title of a treatise published in 1693, the apothecary-physician Samuel Dale's *Pharmacologia seu Manuductio ad Materiam Medicam.* What Dale understood by "*pharmacologia,*" he expressed as follows: "*est pharmacologia descriptio rerum medicamentalium ad bene medicamendum.*" The "*bene medicamendum,*" the best possible employment of drugs or, to put it in another way, a rational therapy, was finally emphasized as the goal of the science of medicine, the knowledge of drugs being only one of the means of achieving this goal.

The term *pharmacologia* as such or in its vernacular modifications (pharmacology, *Pharmakologie, farmacologia,* etc.) became gradually the title of choice for treatises devoted to the action of drugs rather than to the description of their physical appearance, etc. In the time of transition about 1800, it was F. A. C. Gren's *Handbuch der Pharmakologie oder die Lehre von den Arzneimitteln* (manual of pharmacology or the science of drugs) which exerted a fargoing influence. It is of interest that, like Dale, Gren too was an apothecary-physician; that is, he had studied and practised pharmacy as well as medicine. Rudolf Buchheim's classical work brought general esteem to the new endeavor as well as to the new term. However, Buchheim did not create the one or the other.

Since, after all, the effect of the drugs is the part of essential interest to medicine, the term pharmacology (from pharmacon = drug and logos = the sense or essential) has been quite a significant designation of a science which was to develop from the outside of the matter concerned to its inside, from the description of the factual or accidental to the finding and interpretation of the essential. Nevertheless, it is doubtful whether the new term would have achieved its generally recognized place and special meaning in Germany first and gradually all over the world, had it not have been for the fact that just at the decisive time (in the early nineteenth century) pharmacy took over the descriptive part of the "materia medica" of old, now more or less neglected by modern medical research and teaching, and developed it into a science working with modern means on the systematic identification of drugs and their botanical, physical, and chemical classification.

The French pharmacist N. J. B. G. Guibourt is credited with having definitely established this new branch of science in his *Histoire naturelle des drogues simples* (1820). It was, however, in Germany that a new and distinguishing name was coined for the new science. As far as we know, this name, pharmacognosy (*Pharmakognosie*) appeared for the first time in the title of a doctoral thesis submitted at Halle in 1815 by a student of medicine, C. A. Seydler. In 1838 Walther published *Pharmakognostisch-pharmakologische Tabellen,* already contrasting the terms and what they stand for. Derived from pharmacon = drug and gnosis = a knowing, the new name pharmacognosy placed the science of knowing the drugs

as such properly besides pharmacology, the science of inquiring into the essential meaning of the drugs — their effects.

Although early and generally accepted in Germany and the countries under German cultural influence, it took a long time until the term *pharmacognosia* (pharmacognosy, *Pharmakognosie, pharmacognosie, farmacognosia*) found worldwide recognition. In France it was not until the early twentieth century (1907 by Perrot), and in England it was noticed rather than recognized until 1933 when H. G. Greenish changed the title of his renowned *Textbook of Materia Medica* to *Textbook of Pharmacognosy*. Into the United States the term pharmacognosy was introduced by Fr. B. Power's translation of F. A. Flückiger and A. Tschirch's *Grundlagen der Pharmakognosie* (Berlin 1885) which was published in 1887 at New York under the title *The Principles of Pharmacognosy*.

Alexander Tschirch defined the term pharmacognosy in his *Handbuch der Pharmakognosie* (ed. 2, 1930) as follows: "By the name pharmacognosy we understand the science whose task it is to scientifically investigate, correctly to describe, and to systematize according to general points of view the drugs of vegetable and animal origin *with the exception of the physiological effect*. . . . The final task of pharmacognosy will be to group the drugs according to their contents . . . and to come gradually to a pharmaco-chemical system of drugs that serves as a lead to pharmacology."

The founder of the most modern school of pharmacognosy, the Viennese pharmacist-physician Richard Wasicky, has come to a still closer contact with pharmacology by making the action of drugs the basis of his scheme of drug systematization. He illustrates his idea of the interdependence of the science of the effect of drugs and the science of the qualities of drugs by the following scheme:

Pharmacology = Science of drugs.

- I. *Pharmacodynamics* = Science of the effect of drugs.
- II. *Pharmacognosy* = Science of the chemical and physical qualities of drugs.
  1. *Physiopharmacognosy* = Science of the drugs still closer to nature; that is, drugs of vegetable or animal origin.
  2. *Pharmaceutical chemistry* = Science of the drugs representing chemical individuals.

Whatever else may be concluded from the development described above, it has become clear beyond dispute that the term "pharmacology," instead of being "an old synonym for pharmacy" was created and gradually accepted in order to differentiate between the developing medical science, based on physiology and devoted to the action of drugs, and a pharmaceutical science, based on chemistry and botany and devoted to the knowledge of drugs, for which the designation "pharmacognosy" was created and gradually recognized.

If we accept the scheme (and concept) of Wasicky, it would be "pharmacodynamics" which would have to be replaced by the new medical, or medicobiological, science of "biotrepy."—GEORGE URDANG, Director, American Institute of the History of Pharmacy, Madison, Wis.

The name of one of the early German writers on *Pharmakologie* is spelled Buchheim, as above; not Bucheim, as in the article on biotrepy.—ED.

On Meeting the Authors

As one of the newer subscribers to THE SCIENTIFIC MONTHLY I want to tell you how much I have enjoyed the magazine and how much I regret not having received it regularly before. It is interesting, instructive, and particularly valuable to a physician as a means of broadening his outlook and keeping him informed about advances in other fields.

As Directing Librarian of The Cleveland Medical Library I cannot help discussing one feature of your magazine that I do not like. I refer to your policy of placing biographical sketches, titled "Meet the Authors," in the section devoted to advertising. In this position the material is usually discarded when the journals are bound. In its final form, therefore, the magazine gives no indication as to the identity, connections, experience or training of authors aside from the bare name. This I consider unfortunate because the magazine has permanent value, and I am sorry to see such important material discarded.

Two methods of correction occur to me: I would prefer that the biographical material be included as a footnote on the first page of the article. This interferes somewhat with the appearance of the first page, but I believe it is justified. If you prefer, it might be just as satisfactory to place this material at the end of the article. Some magazines, particularly the *Bulletin of the Medical Library Association*, contain biographical material in the body of the magazine as a regular department. This is satisfactory in the bound volumes but has the disadvantage that the biographical material is not available in reprints.

In connection with this problem the following comparisons are interesting. The autumn number of *The American Scholar* contains 20 biographical sketches. They range in length from 12 to 60 words, each averaging about 38, and are carried as footnotes on the first page of the article. The October number of the *Bulletin of the Medical Library Association* carried 9 biographical sketches, ranging in length from 26 to 110 and averaging 55 words each. These are carried as a regular feature of the magazine in a separate section. The November number of THE SCIENTIFIC MONTHLY carried 9 biographical sketches, averaging

143 words and ranging in length from 26 to 413. Dismissing three, which were short because they had been given in full previously, leaves 6 sketches averaging 200 words each. It is obvious that THE SCIENTIFIC MONTHLY carries longer biographical sketches, which I like very much. I do wish they could be so placed that they would not be discarded on binding, and I prefer to have them as part of the reprints.

I feel certain that the feature of which I complain is not disturbing to many of your readers, but I do believe that it detracts somewhat from the value of the magazine in its final form. Despite this criticism, I congratulate you on the excellence of the journal and reassure you that I enjoy it very much.—ROBERT M. STECHER, M.D.

In a few instances Dr. Stecher's second suggestion has already been carried out, as for example on page 179 of the September 1944, issue. It cannot be done consistently, however, because half-tone engravings of the authors' photographs would not reproduce well on the antique paper of which most of the Monthly is composed. Until more coated paper can be obtained, it will be necessary to continue the present practice, and it is hoped that those who bind the Monthly can bind all of it.—ED.

Multiple Hypotheses

Last night I read Dr. T. C. Chamberlin's wonderful article on "The Method of Multiple Working Hypotheses," in the November number. This afternoon (Sunday) I took up my Greek Testament, but instead of reading a bit of the text I decided to read the essay[1] of Westcott and Hort on methods of textual criticism. Very soon I was struck by the similarity of their scientific attitude and method in biblical criticism to those so urgently emphasized by Professor Chamberlin in geology.

I call your attention to this because it is really remarkable how fundamentally alike the two articles are, though in different terminologies. Westcott and Hort dealt with a mass of ancient manuscripts, fragmentary or complete, of mixed and multiple ancestry repeatedly fusing and differently separating, forming as complex and involved a field of study as the geological examples cited by Chamberlin. They insist on the same rigorous scrutiny of the facts, guided by multiple hypotheses, re-examined in the light of the suggested relationships, new facts recognized in sequence and hypotheses confirmed or rejected or new ones formed. There is the same warning against a favored or attractive hypothesis: "It is dangerous to fix the mind . . . on any kind of internal probability: the bias thus inevitably acquired can hardly fail to mislead. . . . Criticism . . . involves not a single but a threefold process: tentative examination . . . , examination . . . by means of the materials thus collected, and final decision. . . . It thus makes all variations contribute to the interpretation of each."

Westcott and Hort study the genealogy of documents to determine degrees of authority. They consider the classes of textual evidence and the kinds of probability in conflicting readings. They insist on complete, impartial, objective investigation as precedent to final interpretation, but they canvass the field for every possible explanation of the facts in evidence. They make new studies as new facts or theories suggest them, and when a well-supported hypothesis appears to have been made untenable, a new study may confirm or reject it.

They show the same impartial, observant, comprehensive, cautious scientific attitude of mind as Dr. Chamberlin, the same rigorous self-discipline, the same precision of language and statement. But only a reading of their essay can make one realize the beautiful perfection of their scientific attainments. Perhaps they never thought of themselves as scientists but certainly today they would be so regarded.—PAUL B. JOHNSON.

[1] In the appendix (pp. 543–46 and 559–61) of *The New Testament in the Original Greek*. Text revised by Brooke Foss Westcott and Fenton John Anthony Hort. Harper and Brothers, New York, 1893.

Additional Medalists

Referring to my article "National Academy of Sciences Medal Awards," Dr. William K. Gregory calls attention to the absence of the following names in the list of recipients of the Daniel Giraud Elliot Medal:

George Howard Parker, 1937
Malcolm Robert Irwin, 1938
John Howard Northrop, 1939
William Berryman Scott, 1940

The presentation of the last three was not completed until after the article was practically through the press.

The manuscript closed with the end of the calendar year 1943. All four of the presentations were made in 1944 including that to Dr. Parker.

In the case of the Elliot Medal the date following the name is that of the publication of the work for which the award is made and is not that of the award or presentation. This was explained in the first paragraph of the article.—PAUL BROCKETT.

Ajax

On page 54 of the January issue appeared a poetic tribute by John G. Sinclair to A. J. (Ajax) Carlson, who "stands foursquare to foes of truth as leader or alone." Dr. Sinclair's sonnet was purposely placed after the article by Anne Roe on "Alcohol Education in the Schools" because Dr. Carlson is a leader in national study and action on the problems of alcoholism. He suggested that we publish Dr. Roe's article.—ED.

THE BROWNSTONE TOWER

Although the editor has not made a thorough study of the history of THE SCIENTIFIC MONTHLY (SM) and its predecessor, *The Popular Science Monthly* (PSM), he has learned enough to explain the origin of recent policies of the SM.

The PSM was established in 1872 by J. W. Youmans, who saw the need for a periodical that would bring to the educated public authoritative information on, and interpretation of, the progress of science. Mr. Youmans hoped that even high school graduates would become interested in his magazine and would broaden their education by reading it. Because there were no professional science writers in those days, Mr. Youmans had to get his principal articles from scientists themselves. Whether it was by design or by necessity, he began and maintained his magazine on a high plane. No doubt his hopes for its popularity were never realized, for it was a financial liability to his publishers.

In 1900 Dr. J. McKeen Cattell took over the PSM and continued the policies of the founder. In the first issue edited by him he wrote: "In the future, as in the past, The Popular Science Monthly will afford an accurate and authoritative record of the progress of contemporary science, and besides being indispensable to the professional investigator, it will seek to secure that popular interest and support which are of essential importance to the course of scientific progress." Under his editorship and business management the PSM grew stronger, probably not because of greater "popular interest and support" but because science was rapidly becoming more diversified and specialized and increasing numbers of professional scientists wanted his magazine in order to keep abreast of developments in fields other than their own. As time went on Dr. Cattell sensed the rising tide of public curiosity about science—curiosity that he could not satisfy without changing the character of the PSM. More and more manuscripts that were not in character had to be rejected, and Dr. Cattell came to the conclusion that the word "Popular" in the title of his magazine was a misnomer. Consequently in 1915 he changed the name of his magazine to THE SCIENTIFIC MONTHLY and disposed of the old name to publishers who ever since have produced a truly popular magazine, appealing to people who are interested in applied science.

In the masthead of the first issue of the SM, Dr. Cattell announced that he would publish "articles appealing especially to educated readers as opposed to purely popular matter appealing to the public generally," and so he did as long as he controlled the policies of the SM.

Now the SM is published by the American Association for the Advancement of Science and is edited by an employee of the Association. It is neither his desire nor his prerogative to impose his views on policy upon the SM. His policies are subject to modification by suggestions and criticisms from members of the Association who take the SM, which is their magazine, not the editor's. It is only to stimulate criticism that the editor now states his present conception of the character and purpose of the SM and his vision of its future development.

The history of the PSM-SM shows that its nature has not changed essentially during the seventy-three years of its life and that the very core of its unique and stable character lies in the fact that its articles have always, with few exceptions, been written by scientists. However the SM may change in content, the present editor believes that its articles should continue to be written by professional scientists, partly because the SM is the only American magazine devoted exclusively to providing an outlet for the literary talent of scientitsts of all kinds. The SM is, and, we hope, will remain, the literary magazine of science.

The purpose of the SM has changed somewhat since it was founded as the PSM in 1872. The original intent to make it a truly popular magazine of science was never realized and it became primarily a magazine for scientists—to keep them informed of developments in fields of scientific thought and action outside of their own. But the original purpose of the PSM has never been given up entirely. The present masthead of the SM describes it as "An illustrated magazine broadly interpreting to the thoughtful public the progress of science and its relations to the problems confronting civilization." This quotation expresses an intention and a hope rather than a fully accomplished fact, but it is a worthy hope that the editor will strive to bring closer to reality.—ED.